DELAWARE ESTUARY

MONITORING REPORT

Covering Monitoring Developments and

Data Collected or Reported during 1999 - 2003

Report Prepared by:

Edward D. Santoro, M.S.

Delaware River Basin Commission

Monitoring Coordinator

In Cooperation with the DRBC

Monitoring Advisory Committee

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LIST OF ABBREVIATIONS AND ACRONYMS

ASMFC	Atlantic States Marine Fisheries Commission
AVS	Acid Volatile Sulfides
BCI	benthic condition index
CCMP	Comprehensive Conservation and Management Plan for the Delaware Estuary
C&D	Canal Chesapeake and Delaware Canal
CPUE	Catch per unit effort
CSOs	Combined Sewer Overflows
DELEP	Delaware Estuary Program
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorous
DO	dissolved oxygen
DNREC	Delaware Department of Resources and Environmental Control
DRBC	Delaware River Basin Commission
EEZ	Economic Exclusion Zone
EPA	U.S. Environmental Protection Agency
ERL	effects range low
ERM	effects range median
FDA	U.S. Food and Drug Administration
FMP	Fisheries Management Plan
gC/m^2yr	grams of carbon per square meter per year
GIS	geographic information system
HABs	harmful algal blooms
HMW	high molecular weight
km^2	square kilometer
LA	Load allocation (non-point source)
lbs	Pounds
m	Meter
MAIA	Mid Atlantic Integrated Assessment
m^2	square meter
mg/L	milligram per liter
mi	Mile
Mm	million metric
NCA	EPA's National Coastal Assessment Program
ng/g	nanograms per gram
NHEERL	National Health and Environmental Effects Research Laboratory
NJDEP	New Jersey Department of Environmental Protection
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
ISSC	Interstate Shellfish Sanitation Conference ISSC
PADEP	Pennsylvania Department of Environmental Protection
PAHs	polycyclic aromatic hydrocarbons
PBB	polybrominated biphenyls

PBDEs	polybrominated diphenyl ethers
PCBs	polychlorinated biphenyl congeners
POTW	publicly owned treatment works
ppm	parts per million
REMAP	Regional EMAP
RM	River Mile (Measured from the seaward extent towards upstream)
SAV	submerged aquatic vegetation
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
SSB	spawning stock biomass
WWTPs	Wastewater treatment plants
t	metric tons
TMDL	total maximum daily load
TN	total nitrogen
TOC	total organic carbon
TP	total phosphorus
ug/l	microgram per liter
USACOE	U.S. Army Corps of Engineers
USFWS	USFWS U.S. Fish and Wildlife Service
USGS U.S.	Geological Survey
VOC	volatile organic compounds
WLA	Waste Load Allocation
VPA	virtual population analysis
YOY	young of the year

EXECUTIVE SUMMARY

The Delaware Estuary Monitoring Report summarizes data and monitoring program developments for the 1999-2003 calendar years. This report was prepared by the Delaware River Basin Commission (DRBC) Monitoring Coordinator under the direction of the DRBC Monitoring Advisory Committee. It fulfills a program element of the Comprehensive Conservation and Management Plan (CCMP) for the Delaware Estuary.

The Delaware Estuary is an interstate watershed that occupies over 6,700 square miles in three states: Delaware, New Jersey, and Pennsylvania. It extends 134 miles from the mouth of the Delaware Bay between Cape May, New Jersey, and Cape Henlopen, Delaware upstream through Wilmington, Camden, and Philadelphia to the falls of the Delaware River at Trenton, New Jersey. Its tributary watersheds drain urban, suburban, and rural communities. Many industrial areas affect in different ways the water quality and habitat in the Delaware Estuary.

The Delaware Estuary is a major transportation corridor and home of the world's largest freshwater port, the Philadelphia port complex, and the second largest oil port in the United States. The Delaware Bay also handles about 85% of the East Coast's oil imports and serves six major refineries. In 2002, ports along the Delaware River and its tributaries handled about 118 million tons of imports and 75.4 million tons of exports.

The hydrodynamics of the Estuary are influenced primarily by the inflow of freshwater, the pulsing circulation of oceanic currents, and the wind. Approximately 60% of the freshwater inflow arrives in the Estuary from the mainstem of the Delaware River at Trenton and another 10% flows in from the Schuylkill River. The remaining freshwater flowing to the Estuary comes from other Estuary tributaries and overland. Since riverine water flow is of major importance to the Estuary, the current report includes sections dealing with hydrological conditions and water use analysis. Much of the water withdrawn in the Estuary is used for cooling purposes in power generation.

There are three major ecological zones in the Estuary, distinguished by differences in salinity, turbidity, and biological productivity. The upper zone is characterized by freshwater under tidal influence and extends from Trenton downstream to Marcus Hook. The transition zone lies between Marcus Hook and Artificial Island; it has a wide range of salinity (from 0-15 parts per thousand) and is characterized by high turbidity and low primary biological productivity. The lower zone is open bay, extending to the Atlantic Ocean, and has higher salinity, large areas that are fairly shallow, and the highest levels of primary biological productivity.

Geophysical studies of estuary sediments by the University of Delaware show that much of the sediment influx is initially deposited in channel and shoal environments of the estuarine mainstem, where it undergoes numerous re-suspension-deposition cycles before becoming permanently sequestered in fringing salt marshes of Delaware and New Jersey. Based upon those studies most of the estuary consists of reworked sediments with distinct areas of deposition and non-deposition. There does appear to be a transition from a dominantly coarse-grained (sand and gravel) in the upper estuary from Philadelphia north to fine-grain (clayey silt to silty clay) bottom type centered near the Delaware/Pennsylvania border. This suggests that much of the estuary is erosional in nature. Sediment characteristics and spatial distribution suggest a very dynamic system, whereby physical processes mix and remix sediments. Areas identified as depositional were in close proximity to non-depositional areas.

Commensurate with sediment mapping, core samples were taken from the open estuary and marsh areas to determine sedimentation rates. Sedimentation rates computed from the CS-137 profiles indicate accumulation rates of 0.3 to 1.5 cm/year. The results of this study were used to inform the hydrodynamic and sedimentation modeling efforts for use in the development of a TMDL for PCBs in the Delaware Estuary.

Dissolved oxygen data show dramatic improvements over the period at the Philadelphia area sampling stations, RM84 through RM111. The mean value at almost every sampling station remained above the average value of 4.5 mg/l at Philadelphia area stations. No significant sag occurred from the summer of 1998 through 2003. Dissolved oxygen levels during the monitoring period reversed a three-to-four-year decline that had slightly eroded prior gains. During the summer months, the seasonal decline in dissolved oxygen was minor, where two decades earlier it had been dramatic. Improvements in dissolved oxygen levels in the Camden-Philadelphia area have been substantial since the late 1970's.

Bacteria and nutrients showed generally positive trends being below criteria. Main channel bacteria counts remained within federal and DRBC standards for the length of the estuary for the fifteenth consecutive year. The 1998-2003 main channel (boat run) data for bacteria showed mean annual (March through November) levels below the federal primary contact recreation standards. In contrast with bacteria trends in the main channel, shoreline and tributary data for the years 1998-2003 show persistent exceedence of the federal criteria in the tributaries over the reporting period in the tidal portions of the Delaware River where recreational contact may be more frequent.

Nutrient loadings to the estuary in 1998-2003 continued to be elevated, but with a continued absence of eutrophic effects. Chlorophyll levels and nutrients in this report were consistent with NJDEP monitoring results for this time period. However, it is important to note that measurements taken at the channel are not necessarily representative of the entire estuary. Differences exist between the levels of parameters such as dissolved oxygen and nutrients between the channel locations where DRBC monitors and other portions of the bay. For example, based on NJDEP monitoring data, chlorophyll *a* levels at the channel average around 6 μg/L whereas non-channel stations average around 9 μg/L. Also, nitrate levels tend to be higher at channel stations than at non-channel stations. Overall variability of the data at the channel tends to be much less that at more inshore locations. This is especially true in the lower portion of the bay.

In Delaware Bay, areas considered safe for shellfishing decreased slightly. At the end of 2003, the State of New Jersey classified 235 acres within the Maurice River Cove from Approved to Seasonally Approved. There are a few areas in the bay where water quality restrictions limit shellfish harvesting. Prohibited areas cover approximately 15.6 percent of the bay, or slightly fewer than 70,000 acres. They primarily occur north of the Smyrna River on the Delaware side and north of Artificial Island on the New Jersey side. Approved areas cover 377,579 acres.

There continues to be widespread fish advisories in the Delaware Estuary, predominantly from PCB contamination. The best available information currently indicates that point sources are the second-largest PCB loading source to the estuary. However, there are many significant sources not regulated by the NPDES program. It is evident that point source controls alone would not result in sufficient reductions to eliminate fish consumption advisories based on PCB contamination. Implementation of a broad-based effort to achieve PCB reductions from point and non-point sources will be necessary.

For the first time the Monitoring Matrix presented in Appendix 12.1 includes information on volunteer monitoring programs within the Delaware River Basin in addition to information regarding Federal and state agency monitoring programs.

Delaware oyster abundance ranged from 350 oysters per bushel to slightly less than 100, and recently these resources have shown a substantial drop to the low end of the range. Historically, in the Delaware Estuary, oysters were removed from the seed beds and planted on leased grounds farther down bay. The four year period of very low spat abundance from 2000 to 2003 has caused a significant loss of oyster resources in the higher salinity parts of the seed beds. If this trend continues it will yield a continued reduction in oyster abundance throughout the Delaware Estuary.

Regarding the horseshoe crab, researchers conclude that spawning activity in the Delaware Bay over the past 5 years has been either stable or declining at a rate of less than 8% per year. Spawning activity appears to be more stable in New Jersey than in Delaware. The restrictive measures introduced in the Delaware Bay region on harvesting, the implementation of the Carl N. Shuster Jr. Horseshoe Crab Reserve (CNSJrHSCR), and the utilization of bait bags seem to be benefiting the horseshoe crab population. However, the increase is not substantial enough to warrant any less restrictive measures in the management of the species.

The population of striped bass in the Delaware River has experienced a remarkable recovery within the last decade, largely attributable to improved water quality and strict fishery management measures. Over the past 5 years the striped bass harvest has stayed at approximately 2,500,000 to 3,500,000 fish. Recent estimates indicate the juvenile striped bass index for 2003 will be a record high value.

Based upon hydroacoustic methods, an estimated 300,000 American shad returned to the Delaware River to spawn in 2003 indicating a decline of approximately 40 percent from the 2002 population. The fluctuation in population over the report period likely reflects natural variation.

Over the report period the abundance level of weakfish has ranged from approximately 220 weakfish per nautical mile in 2001 to 100 in 2002 (the last year reported). Some of the fluctuation in abundance may be due to changes in fishing pressure.

1.0 HYDROLOGICAL CONDITIONS 1999-2003

1.1 Delaware River Basin Hydrology

The 1999 to 2003 period demonstrated that hydrology is a study of extremes. It included one of the most prolonged and intense drought periods since the record drought of the 1960's, and ended with 2003 producing the highest average annual flow on record for the Delaware River at Trenton, NJ.

Figure 1.1.1 presents the total monthly precipitation for January 1999 through December 2003. The totals are the average for the Delaware Basin above Trenton, NJ, reported by the National Weather Service's Mid-Atlantic River Forecast Center. Also shown is the normal monthly precipitation for each month for the period 1971-2000. With the exception of Hurricane Floyd in September 1999, the period from January 1999 to July 2002 was very dry. Precipitation deficiencies occurred in 24 of the 43 months and deficits exceeded one inch in 13 of the months. The period beginning in June of 2003 was extremely wet and produced record seasonal and annual average flows at Trenton, NJ

Figure 1.1.2 presents the accumulated precipitation deficit for the period June 1998 through December 2003, averaged above Trenton, NJ. The 1998 period is included because the lack of precipitation beginning in July of 1998 contributed to the extremely dry conditions, particularly in the Lower Delaware Basin, during the summer of 1999. The average deficit built to as high as 16 inches (approximately one third of the total annual precipitation) by March of 2002 and persisted until the heavy rains during the second half of 2003.

Figures 1.1.3 and 1.1.4 present the 7-day mean and 7-day median flows for the period 1971 through 2000 for the Delaware River at Trenton, NJ. These plots indicate total runoff, including ground water discharge or base flow, and provide a representative indicator for total estuary inflow. The plot of median 7-day flows shows that the most significant extended periods of below normal inflow to the estuary occurred from March to September of 1999 and from September 2001 to April of 2002. The extremely high flows beginning June 2003 are also illustrated on the plot.

Figure 1.1.5 presents the U.S. Geological Survey's Streamflow Conditions Index for the States of New Jersey, Delaware, and Pennsylvania since July 2, 1999. This index represents the daily average index value (a value based on the percent of time the observed flow rate is equaled or exceeded) for all gauging stations in the respective state. The Pennsylvania plot is less representative of Delaware Basin conditions due to the large geographic area of the state located outside of the basin. The New Jersey and Delaware plots are considered most representative of streamflow conditions in the Lower Delaware Basin, and clearly show two distinct periods of deficient streamflow – the summer of 1999 and the period from the early fall of 2001 to late

2002, with the dry period most prolonged in Delaware. The New Jersey and Delaware plots reflect local streamflow effects, and therefore show some differences in timing of the dry periods from the plots for the Delaware River at Trenton.

1.2 Estuary Salt Line Movement

Chloride concentrations in the Delaware River play an important role in the Delaware River Basin Commission's (DRBC) water quality and drought policies. Chloride concentrations have been monitored since the 1960s and in recent years, have been monitored daily using data collected from several automatic monitoring stations along the Delaware River. The DRBC monitors the location of the 7-day average 250 parts per million chloride concentration or "salt line." The location of the salt line is important because DRBC's drought plan focuses on controlling the upstream migration of salty water from the Delaware Bay during low-flow conditions in the basin's rivers and streams. As brackish water moves upstream, it may lead to higher water treatment costs for water suppliers and may also lead to higher corrosion control costs for industries along the river.

1.2.1 Sources of Chloride Data

The DRBC uses daily mean specific conductance data as well as direct chloride measurements from several different sources to determine the location of the salt line. The United States Geological Survey (USGS) is a major provider of daily specific conductance data. Specific conductance data are collected from the Delaware River by four water quality monitors located at Reedy Island, Delaware, Chester, Pennsylvania, Fort Mifflin, Pennsylvania, and the Ben Franklin Bridge, Pennsylvania. After the data are collected, daily mean specific conductance in micromhos units are converted to chloride measurements in parts per million (ppm).

Another source of chloride data used by the DRBC is the Kimberly-Clark Corporation (KCC). Technicians measure chloride concentrations in the Delaware River near the KCC facility in Chester, Pennsylvania (RM 83). Samples are collected at each high and low tide for a total of four samples a day. The daily minimum, maximum, and average chloride measurements are reported to DRBC via e-mail at least twice a week.

1.2.2 Determination of the Salt Line Location

For most of the year, the location of the salt line is determined using the data supplied by the Kimberly-Clark Corporation and the USGS Reedy Island water quality monitor. The location of the salt line is estimated by interpolating between the seven day average chloride concentrations at each station. During dry periods, when low stream flow causes chloride concentrations to increase and the salt line to migrate further upstream, other stations are used for the interpolation process. For example, once the salt line moves above RM 83, data from the USGS water quality monitors at Chester (RM 83) and Ft. Mifflin (RM 92) are used to determine the salt line's location. If the salt line migrates to above the Ft. Mifflin monitoring station, data from the USGS monitor at the Ben Franklin Bridge (RM 100) are used along with the data from the Ft. Mifflin monitor to determine the salt line's location.

1.2.3 Salt line Movement: 1999-2003

Chloride concentrations in the Delaware River vary widely during the course of a year. During wetter times of the year, such as late winter and early spring, the salt line is normally located further downstream in the river. This is due to the higher streamflows in the river that dilute the chloride concentrations. During drier periods of the year, such as the summer and early fall when water use demands and evaporation rates are higher and freshwater inflow into the river is reduced, chloride concentrations will increase and the salt line migrates further upstream.

Dry periods can be a concern with regard to salinity intrusion into drinking water supplies. During such times, saline water threatens to intrude on Philadelphia's drinking water intake at the Delaware River at Torresdale. During periods of low streamflow, releases may be directed by the DRBC from Blue Marsh and Beltzville reservoirs in the lower basin. These releases augment streamflow along the Delaware River, providing additional freshwater to dilute chlorides and maintain the salt line below the mouth of the Schuylkill River (RM 92).

The five years between 1999 and 2003 contained a mix of wet periods (2000 and 2003) and dry periods (1999 and 2001-02). During this time, the salt line ranged from below RM 54 (the furthest downstream location the DRBC measures) to as high as RM 89. During the wettest years, the 250-ppm chloride concentration stayed at or below the normal mid-month locations for most of the year. For example, during 2003, annual rainfall surpluses of more than 20 inches in some parts of the Delaware Basin kept streamflows above normal for much of the year. As a result, chlorides in the river were kept so diluted that the salt line location was consistently below the normal location (sometimes by as much as 30 miles) from June through December.

Drought plagued the basin twice in the years between 1999 and 2003. The first time was during the summer of 1999 and the second time was for a longer stretch from summer 2001 through autumn 2002. During both of these droughts, the effects of below normal precipitation and the resulting low surface runoff and base flow was mirrored in the salt line's movements. In August 1999, the salt line crept to RM 89, which is near the location of the Philadelphia International Airport. Fortunately, Hurricane Floyd blew through the basin less than one month later raising streamflows to levels that swiftly pushed the salt line back to below the normal level for that time of year. During the second drought of the five year period, the salt line reached RM 89 by late September 2001. Relief arrived shortly after in the form of heavy rainfall that pushed the salt line back toward the Delaware Bay.

Figure 1.2-1 shows the Location of the 7-Day Average of the 250-ppm Isochlor for a graphical representation of the salt line movement over the period 1999-2003. **Figure 1.2-2** presents a map depicting the locations of the water quality monitoring stations used to monitor the salt line and shows the furthest upstream Location of the 7-Day Average of the 250-ppm Isochlor over the report period.

1.3 Water Use in the Estuary

Withdrawals and consumptive uses have been analyzed for the Estuary as a whole and also on a sub-basin basis. **Figure 1.3-1** presents the change in population between 1990 and 2000.

In 1996, water withdrawals in the Estuary watershed accounted for approximately 83% of total withdrawals in the Delaware River Basin. Water use by sector is shown for both total withdrawals and consumptive use in **Figures 1.3-2 a-f** and **Figures 1.3-3 a-f** respectively. Although data are presented for 1996, this broad assessment of water use is the most recent available and assumed valid for the monitoring period 1999 through 2003. While it is useful to consider relative water withdrawals, it is often more informative to examine consumptive uses.

The significance of consumptive use is that it measures how much of the withdrawal volume is not directly returned to the hydrologic system for downstream users, or to meet instream flow needs.

<u>Schuylkill Valley</u>:
Public water supply and thermopower generation each account for around 40% of withdrawals and consumptive use. Mining and industrial withdrawals each make up half of the remainder. Consumptive use is also largely attributed to public water supply and power generation in this sub-basin, which combined account for 75% of total consumptive losses.

<u>Upper Estuary:</u>
Withdrawals in the Upper Estuary are dominated by the power sector, accounting for 75% of the total. However, power facilities in this region are not highly consumptive in nature and therefore that sector represents only 15% of total consumptive use, similar to the industrial sector. Public water supply accounts for over 50% of the consumptive use in 1996.

<u>Lower Estuary:</u>
Withdrawals in the Lower Estuary are dominated by the power sector, accounting for over 85% of the total. There are very few public water supply withdrawals in this sub-basin; none on the mainstem of the river. Power generating facilities located in this sub-basin are more consumptive and account for more than 65% of total consumptive use. Industry, agriculture and public water supply each account for approximately a third of the remainder.

<u>Delaware Bay:</u>
The Delaware Bay is the only Estuary sub-basin that does not have power generation facilities. Here, the dominant uses are for public water supply, mining, and agriculture – the latter accounting for over 50% of consumptive use in the sub-basin.

Estuary:
In summary, much of the water withdrawn in the Estuary is used for power generation. The Estuary is home to the majority of power generating facilities in the Delaware River Basin which all withdraw large quantities of surface water. Over 92% of withdrawals by thermo-electric power generating facilities (those that have some consumptive use component) are located in the Estuary, mainly in the Lower and Upper Estuary sub-basins. However, in terms of consumptive use, the power sector (at 34% of total consumptive use) is only slightly larger than public water supply (32%). Industrial, agricultural, and mining operations, in that order, account for the majority of the remainder. The relative proportions of water withdrawn and consumed in the Estuary closely reflect those of the Delaware River Basin as a whole.

2.0 DATA COLLECTION AND INTER-AGENCY COORDINATION

2.1 DRBC Boat Run Program Developments

The DRBC's boat run program, begun in the late 1960s, collects water quality data from the center channel of the main stem Delaware River and Delaware Bay. Twenty-two stations were sampled twelve times per year from March - October during the report period. These stations extended from RM 127.5, a short distance south of Trenton, New Jersey, to South Brown Shoal in Delaware Bay at RM 6.5, near the bay mouth. The stations are plotted on an estuary map in **Figure 2.1-1** and listed by RM and geographic coordinates. T**able 2.1-1** identifies the parameters for which data are collected at each station. Data categories include routine pollutants: bacteria and radioactivity; heavy metals; algae and organic carbon; and oxygen demand. Additional surveys for other pollutants are performed on an as - needed basis.

2.2 National Coastal Assessment Program

The National Coastal Assessment (NCA) program developed by USEPA was developed to establish a baseline of environmental conditions for the estuaries of the coastal states as part of a national survey of estuarine condition, and trace changes in that condition through time. The intent is to create a base of data/information that supports assessments at national, regional, and state levels.

The goal of the program is to assess the ecological condition of estuarine resources at multiple scales for the entire country to determine reference conditions for ecological responses/stressors and to build the infrastructure in EPA Regions and in states in order to ensure continued monitoring and assessment.

The program utilizes a probabilistic monitoring design to evaluate reference conditions for estuaries in the United States. This probabilistic design was developed by USEPA using ecological response indicators, along with diagnostic indicators. The strata were developed using biogeographical provinces. For the northeastern US, these are the Acadian & Virginian provinces (the sub-strata in Delaware Bay includes the coastal states). Proportional sampling includes all types of estuaries which are classified by size.

The NCA program has set up cooperative agreements with the states. The state matches program contributions with in-kind services. The strategy is to partner with state resource agencies for design of the monitoring program, collection and processing of samples. This will help to develop state and regional infrastructure and develop state and regional capacity. The NCA Target Species include the following; Channel Catfish, White Catfish, Scup, Summer Flounder, Weakfish, White Perch, Winter Flounder, and Blue Claw Crab. The current sampling stations from which data are collected under this program over the period 2000-2003 are presented in **Figure 2.2-1.** Organisms were collected from trawls within the Delaware Bay and tidal tributaries. A complete list of the fishes collected in 2000-2002 is presented in **Table 2.2-2**. A list of the 564 benthic infauna species collected from sediment samples during the 2000 season is provided in **Appendix 12-2.**

Only the 2000 data were available at the time of this report. A summary report of the findings of the NCA program for the Northeast is presented in EPA (2004). That report presented only the data for the 2000 sampling year for one sampling event at 35 stations in the Delaware Estuary regarding water quality, coastal wetlands, sediment condition, benthic condition and fish contaminants collected under the program.

2.2.1 Fish Tissue Analyses collected for the DRBC during the USEPA National Coastal Assessment Program

Beginning in the 1980's, a number of studies of contaminant levels in resident and anadromous fish species, invertebrates such as the blue crab, and shellfish have been conducted by federal, state and interstate organizations (see, e.g., DRBC, 1988; Greene and Miller, 1994; Hauge *et al.*, 1990; U.S. F&WS, 1991 and 1992). These studies were expanded in scope and frequency after 1989 when the states bordering the Delaware River began to issue advisories banning or limiting the consumption of certain species. With funding from DELEP, the DRBC and DNREC prepared a report that summarized the data on contaminants in biota and described the current approaches used by the states in developing their fish consumption advisories. **(http://www.state.nj.us/drbc/fishtiss.htm).** A list of the organisms collected and analyzed under this DRBC activity during 2000-2002 is presented in **Table 2.2-3**

The DRBC worked with the NCA chemistry laboratory, Arthur D. Little, (ADL) to "merge" its program requirements for additional analytes and the analysis of edible tissue into the existing analytical framework. With moderate matching funds, DRBC arranged for ADL to analyze fish fillet and Blue Crab samples collected in Delaware Bay for additional PCB congeners using DRBC protocols, beyond the NOAA 18 standard congeners analyzed in the NCA Program. In cooperation with the USEPA Program management, DRBC selected fish samples to be filleted. The fillets and offal were analyzed separately for NCA parameters as well as the additional congeners needed by DRBC for fillet samples. ADL reported results for the fillet samples to DRBC, which will be using these data to determine congeners of concern in the Delaware Bay System and for trend analysis. The laboratory summed fillet and offal data by weight percent to provide NCA with whole body results consistent with the national program requirements. During 2000, 45 additional samples of Blue Claw Crab, White perch, Channel Catfish and Weakfish representing 321 organisms were collected and analyzed for use by DRBC. A list of the samples analyzed are presented in **Table 2.2-3**. By working with the USEPA, The National Laboratory Contractor, and the NCA Program, the DRBC was able to expand the analysis of fish samples beyond that mandated by NCA to meet its program needs. During the 2000-2003 period, a number of fish species were collected in this program. The numerical abundance of the major species collected is presented in **Figure 2.2-2.** This figure shows that the collection was dominated by spot, striped bass, and weakfish.

2.3 Data Analysis of the MAIA Program

Data collected during the Mid Atlantic Integrated Assessment Program (MAIA) in 1997 continue to be evaluated by the NOAA members of the Coastal Monitoring Bio-Affects

Division (CMBAD). Aquatic sediment samples of macroinvertebrates collected during the 1997 survey were sorted and identified. Evaluations of this data by NOAA have identified over 18,000 organisms representing 233 taxa collected during the effort in the Delaware Estuary. Based upon the presence of unique taxa, nodal analysis performed by Dr. Ian Hartwell of NOAA (personal communication) suggests that seven habitat types exist within the estuary based upon the salinity regime and sediment grain size. **Figure 2.3-1** presents these habitat types. **Figure 2.3-2** presents a nodal analysis of the species identified. Based upon this nodal analysis, **Figure 2.3-3 and 2.3-4** presents seven species associations which are grouped based upon the physical associations in the Delaware Estuary (Personal communication Dr. Ian Hartwell). These include the following categories:

- Freshwater mud
- Freshwater sand/mix
- Freshwater/saltwater transition zone
- Upper Estuary depositional estuary
- Deep Estuary
- Ocean Tributary
- Atypical area identified as site 64 (this category was not grouped within any other cluster)

2.4 Sedimentology and Geophysical Studies of the Estuary

The Delaware Estuary experiences a number of environmental and engineering problems related to sedimentation, most conspicuously, chronic infilling of navigable channels and burial of particle-borne contaminants. In this regard, the Delaware is akin to many urbanized estuaries worldwide. The industrialized corridor between Philadelphia and Wilmington happens to be situated in the estuarine turbidity maximum (ETM) zone, an innate feature in river estuaries created by a combination of sediment dynamics and flow patterns. Accordingly, natural processes contribute to the ubiquitous shoaling and contaminant dispersal problems in the upper estuary (Delaware River Basin Commission, 1998A). Despite a substantial outlay to mitigate these problems, a fundamental understanding of mechanisms that govern sediment movement and storage has been elusive. An average 1.4 million metric tons of suspended sediment is delivered annually to the Delaware Estuary from mainstem and tributary river sources (Mansue and Commings, 1974). About 56% of this load is supplied by the Delaware River upriver of Trenton, 20% from the Schuylkill River, 9% from the Christina River, with the remainder derived from numerous Piedmont and Coastal Plain tributaries. During a typical year, as much as 50% of the annual load is supplied during the months of March and April, when rainstorms and snowmelt elevate streamflow. Much of the sediment influx is initially deposited in channel and shoal environments of the estuarine mainstem, where it undergoes enumerable re-suspension-deposition cycles before becoming permanently sequestered in fringing salt marshes of the Delaware and New Jersey shoreline. Most of the sediment in suspension resides in the ETM zone, typically centered between Philadelphia and Artificial Island. Research elsewhere has shown that ETM suspended sediments are sourced from tidal resuspension, whereas the locus and maintenance of the ETM may be caused by processes including flocculation, gravitational circulation, tidal pumping, and stratification, either collectively or mutually exclusive of one another (Jay and Musiak, 1994; Sanford et al., 2001).

A sedimentological and geophysical survey of the upper Delaware Estuary was conducted during 2001–2002 by the University of Delaware (UDel) in cooperation with the Delaware River Basin Commission (DRBC). The estuary between Burlington, New Jersey south to the Smyrna River, Delaware was identified for study. The study objectives were to:

- Perform a systematic, high-resolution characterization of the bottom based on sonar mapping data, sediment sampling and analysis, and a regular classification scheme.
- Quantify sedimentation rates at selected sites within the estuary and fringing tidal marshes using core samples.

The study provided a map of bottom sediment types in the tidal river and estuary and an estimate of sedimentation rates at selected sites in the estuary and tidal marshes. Furthermore, it provides a conceptual framework of the sedimentological regime in the upper estuary. Sediment characteristics and spatial distribution suggest a very dynamic system whereby physical processes mix and remix sediments. Areas identified as depositional were in close proximity to non-depositional areas. **Results of this study were used to inform the hydrodynamic and sedimentation modeling efforts for use in the development of a Total Daily Maximum Load (TMDL) for PCBs in the Delaware Estuary**.

<u>Sediment Survey</u>

Acoustic mapping techniques were used to construct images of the estuary bottom. Sidescan, chirp sonar, and single beam echosounding were used to assess the lateral distribution of morphology, thickness, and continuity of sedimentary strata and bedrock and bottom depths, respectively. Approximately 250 sediment samples were collected to ground truth the sonar data and to provide grain size and porosity measurements. Approximately 350 miles of sonar data were collected and a continuous record was obtained in the study area for water depths exceeding five meters. Geographic position was determined using a Differential Global Positioning System which interfaced with the three sonars. Positional data were considered accurate to within +- 5 meters. Essentially, four distinct types of sediment were identified in the study area:

- Reworked bottom (consisting of fine, mixed and coarse grained sediment)
- Coarse grained bedload bottom
- Non-depositional or erosional bottom
- Fine-grained deposition

The most commonly observed bottom sediment type was reworked sediments, encompassing approximately 75% of all sediment types in the study area. A spatial distribution of the sediment types is presented in **Figure 2.4-1**. Additional features, such as bedload forms, core profiles and depositional profiles, are presented in **Figure 2.4-2.** Bedload features identified in the upper estuary further enhance the interpretation that the Delaware Estuary is a very dynamic system. However, another significant finding is that fine-grained depositional areas also occur in the estuary, primarily in the Marcus Hook through the New Castle area. This finding is consistent with dredging records for the same reaches which indicated that less than 60% of all the sediment dredged in the shipping channel of the Delaware River is dredged from Marcus Hook through the New Castle reach.

Sedimentation Rates

Undisturbed sediment cores for chronological studies were collected using a hydraulically damped corer and push cores. An estimation of the sedimentation rates in the tidal portion of the river below Philadelphia is presented in **Figure 2.4-2**. Sediment accumulation rates were estimated from down core profiles of the artificial radionuclide Cs-137 (t1/2=30 years), a product of nuclear fission. Cesium-137 fallout was first detected in the environment around 1954, and peaked in 1963–1964, and thereafter dropped to insignificant levels by 1980. Therefore, the concentration and distribution of Cs-137 in the sediment column may be used to estimate net accumulation rate averages over the past several decade. Additionally, sedimentation rates were also calculated from another radioactive isotope BE-7 (t1/2=53 days), thus providing depositional information on a seasonal time frame. Results of the sedimentation study indicates that the Cs-137 profile was absent in the open estuary. This suggests that the rates of fine-sediment accumulation in the open estuary are too low, or the bottom too disturbed, for the Cs-137 method to provide reliable chronologies. This result is consistent with sonar observations of a physically reworked bottom. However, samples collected in the marsh areas yield usable Cs-137 concentrations and in particular the core collected at Woodbury displayed the ideal profile, presented in **Figure 2.4-3. Sedimentation rates computed from the CS-137 profiles indicate accumulation rates of 0.3 to 1.5 cm/year.** The PCB concentration in the core collected at Woodbury showed levels of PCBs at the highest concentrations at depths of 40-50 centimeters. Dating of those levels suggest that they were deposited over the period 1963-1974.

Analysis of Be-7 radioisotopes in cores collected in depositional areas suggests a seasonal depositional history in the estuary. Essentially, Be-7 can be detected for a period of approximately five months. Therefore, when detectable concentrations of Be-7 are observed, this indicates that the depositional flux exceeds the rate of loss through decay or physical redistribution. Depositional rates in some cores were on the order of centimeters per month.

The overall framework of sediments in the tidal Delaware estuary range from mud to gravel and are extremely spatially variable. While most of the estuary consists of reworked sediments from natural processes, there are distinct areas of deposition and non-deposition. There does, however, appear to be a transition from a dominantly coarse-grained (sand and gravel) in the upper estuary from Philadelphia north to fine-grain (clayey silt to salty clay) bottom type falls centered on the Delaware-Pennsylvania border. Furthermore, it appears that sedimentation rates in the tidal marshes are more continuous than within the adjacent open estuary.

3.0 WATER QUALITY

The estuary is classified not only as a drowned river valley, but also as a partially mixed and moderately stratified estuary. The salinity of surface waters increases from near zero at Chester, Pennsylvania, to about 30 parts per thousand at the mouth of the estuary. Normally, the estuary is well mixed by strong tidal currents. Suspended sediments in the Delaware Estuary range in size from sand grains to clay particles to colloidal materials. They are predominantly derived from shore and land erosion, and are carried into the estuary by rivers.

3.1 Dissolved Oxygen

The DRBC boat run sampling data indicate that mean seasonal (March-November) dissolved oxygen levels in the main channel were at or near the DRBC water quality criteria for the entire length of the estuary. DRBC criteria are as follows: a 24-hour average of 5.0 mg/l for Zone 2 and 3.5 mg/l for Zones 3, 4 and 5; a minimum of 5.0 mg/l at all times in Zone 6 unless diminished by natural conditions; and a seasonal average (April 1 through June 15 and September 16 through December 3) of not less than 6.5 mg/l for Zones 2, 3, 4, and 5. Notably, mean levels over the report period for the entire boat run stations improved over levels of years prior to 1998. See **Figure 3.1-1** for the location of DRBC zone boundaries.

Plots of average dissolved oxygen concentrations in summertime over the period 1967-2003 periods for each of the boat run stations are provided in **Figures 3.1-2**. The data show dramatic improvements over the period at the Philadelphia area sampling stations, RM 84 through RM111 since 1980.

Notwithstanding the improvement in annual mean dissolved oxygen levels over the length of the estuary by 2003, the mean value at almost every sampling station remained appreciably above average values of 4.5 mg/l at or above at Philadelphia area stations.

Consistent improvement in dissolved oxygen levels during summertime (June through September) conditions of highest average temperature and low freshwater flow were reported recently in other publications (Santoro and Sharp, 1999 and Collier *et al.,* 1999). These reports show steady improvement in summertime levels for the years 1971, 1977, 1987, 1994, and 1998 through 2003. As **Figure 3.1-2** illustrates, during the summer months of 1967 and 1980 serious oxygen sag extended twenty miles, from approximately RM 75 to RM 95. **In contrast, no significant sag occurred during the summers of 1998 through 2003.**

Some monitoring stations in the Delaware Bay, sampled by the states of Delaware and New Jersey, are routinely used along with DRBC Boat Run data for assessment purposes. These data have shown some excursions of dissolved oxygen below DRBC criteria for Zone 6. On the Delaware side of the Bay, three stations (out of six that provide dissolved oxygen data) each exhibited greater than 10% of samples with dissolved oxygen levels less than 5.0 mg/l between 2000 and 2002. The stations which are located in near-shore areas at the mouths of tributaries may reflect water quality impacts from those tributaries. However, this warrants further investigation. On the New Jersey side of the Bay, also between 2000 and 2002, 13 locations (out of 41 that provided dissolved oxygen data) exhibited greater than ten percent of samples with oxygen levels less than 5.0 mg/l.

3.2 Bacteria

Previous data reported by Santoro (2000) for the period prior to 1999 showed a decline in bacteria levels in the main channel of the Delaware River between Trenton and Wilmington. Recent data support this trend. Shoreline and tributary data supplied by DRBC, DNREC, the New Jersey Department of Environmental Protection (NJDEP) and the Pennsylvania Department of Environmental Protection (PADEP) for the years 1998-2003 are compiled and plotted together with the main channel boat run data (see **Figure 3.2-1**). The plot illustrates that although **water in the main channel does not exceed the federal primary contact recreation standards for bacteria, frequent exceedence of the standards persists in tributaries and in shallow areas near the shore, where recreational contact is more frequent.**

The 1998-2003 main channel (boat run) data for bacteria showed mean annual (March through November) levels below the federal primary contact recreation standards. That is, mean main channel data were within the maximum geometric average of 200 colonies per 100 milliliters (200 colonies/100 ml) for fecal coliform, and 35 colonies/100 ml for enterococcus in marine waters and 33 colonies/100 ml for freshwaters. Main channel samples thus met the identical or more lenient DRBC standards, which vary by river zone: for fecal coliform, 200 colonies/100 ml in Zones 2 and 6, and below RM 81.8 in Zone 4; 770 colonies/100 ml in Zone 3 and above RM 81.8 in Zone 4; and for enterococcus, 33 colonies per 100 ml in Zone 2 and below RM 81.8 in Zone 4; 88 colonies/100 ml in Zone 3 and above RM 81.8 in Zone 4; and 35 colonies/100 ml in Zones 5 and 6. **In contrast with bacteria trends in the main channel, shoreline and tributary data for the years 1998-2003 show persistent exceedence of the federal criteria in the tributaries over the reporting period** (see **Figure 3.2-1**).

3.3 Shellfish Closure Areas

The states of Delaware and New Jersey have aggressively regulated the harvest of shellfish in the estuary for many years, in order to protect consumers from diseases caused by water-borne pathogens. Both states participate in the Interstate Shellfish Sanitation Conference (ISSC), a cooperative alliance between the states, the United States Food and Drug Administration, and the shellfish industry, under which shellfish harvesting is prohibited in all areas not expressly approved by the states for harvest. In addition to ensuring clean shellfish growing waters, the ISSC provides for safe handling, processing, packaging, and distribution of the shellfish harvest.

Coastal states classify shellfish growing waters according to ISSC guidelines, based on water quality and shoreline surveys of pollution sources. Areas are classified as *approved for harvest* or assigned one of several *harvest-limited* categories.

The harvest-limited categories for Delaware Bay include:

- Prohibited
- Seasonally Restricted
- Special Restricted

In approved areas, shellfish harvesting is unconditionally permitted year-round. Prohibited areas consist of areas that have been placed off-limits to shellfish harvesting due to a combination of sanitary survey data that indicate actual or potential pollution problems, and/or due to bacteria monitoring. States may use either the total or fecal coliform standard. Delaware uses the ISSC- approved total coliform standards, which are a geometric mean of 70 cells/100 ml for the most recent 30 samples collected per station; and no more than 10 % may exceed 330 MPN cells /100 ml. using a 3-tube dilution test. New Jersey also uses the ISSC approved total coliform standard as well as the ISSC-approved fecal coliform standards which are a geometric mean of 14 cells/100 ml for the most recent 30 samples collected per station; and no more than 10 % of the samples collected may exceed 49 MPN cell/100 ml using a 3 tube decimal dilution test. Delaware uses only the approved and prohibited designations.

New Jersey limits shellfish harvesting in seasonally restricted areas to the months of November through April or January through April. Shellfish harvested in New Jersey waters from either seasonally restricted or defined areas must be relayed to clean waters or to depuration facilities for a designated period of time to reduce their levels of bacteria and viruses before they are processed for human consumption.

Although the large majority of acres are classified based on water quality, prohibited areas include some acreage not tested because it is not fished, and seasonal restricted and special restricted areas include some acreage that is harvest-limited because of competing uses, such as recreation. However, these exceptions to water-quality-based classification are deemed small enough in the Delaware Estuary, that changes in approved and prohibited acreage over time remain a good indicator of water quality trends.

A map of shellfish classification areas in Delaware Bay south of the Pennsylvania-Delaware border is found in **Figure 3.3-1**. **There are few areas in the bay where water quality restrictions limit shellfish harvesting. Prohibited areas cover approximately 15.6 percent of the bay, or slightly fewer than 70,000 acres.** They primarily occur north of the Smyrna River on the Delaware side and north of Artificial Island on the New Jersey side. **Approved areas cover 377,579 acres.**

Figure 3.3-2 shows a graph of approved and prohibited acreage for the years 1990 to 2003. The 377,579 acres of the bay unconditionally approved for harvest in 1998 represented an increase of 2.4 percent, or 8,828 acres, over the corresponding area in 1990.

In Delaware Bay a slight decrease in the areas classified as approved for shellfishing occurred. At the end of 2003 the State of New Jersey modified 235 acres within the Maurice

River Cove from Approved to Seasonally Approved. This delineates those waters as approved for harvest of shellfish for part of the year and as Special Restricted for the remainder of the year. The approved period is from November 1 through the following April 30 of each year.

3.4 Nutrients

The Delaware Bay receives heavy inputs of nutrients primarily from atmospheric, urban and industrial sources. **The mainstem waters flowing between Burlington, New Jersey, and Wilmington, Delaware, have the highest concentrations of nitrogen of any major estuary in the United States. Approximately 50% of the inorganic nitrogen that enters the Delaware Estuary comes from atmospheric input, and it has been estimated that 80% of the phosphate entering the estuary results from human activity**. The Delaware Estuary has been historically very turbid (i.e., light limited). However, historically the Delaware River and Bay have not experienced the typical signs of eutrophication i.e.; fish kills, algal blooms, water discoloration or other effect. The turbidity maximum varies depending upon river inflow but typically occurs near Reedy Island, Delaware. The flushing time (the time a water molecule takes to move out of the system) in the system is typically 90 – 120 days. From the 1960's to the late 1980's large increases in dissolved oxygen and a large reduction in phosphorus had occurred. Over that period there has been little or no change in suspended solids and total nitrogen levels. Currently, the minimum oxygen levels are well above 4.5 mg/l. The DRBC boat run program measures nutrient concentrations and algal biomass, which are useful to determine the river's trophic status. Nutrients, especially phosphorous in fresh waters, are a link to increased algal biomass, although physical constraints, such as light, temperature, and current, can determine the potential for nutrient utilization by algae and aquatic plants. Chlorophyll-a, a green pigment used by algae and green plants during photosynthesis to convert light, carbon dioxide, and water to sugar, is commonly used as an index of algal biomass. Phaeophytin is a degradation product of chlorophyll-a. Thus, the relative distribution of chlorophyll-a and phaeophytin may be used to assess the growth of a phytoplankton community.

Santoro (2000) documented a dramatic increase in nutrient loading to the Delaware Estuary since the early 1900's, associated with dramatic population growth during the first half of the century. That report also noted that high nutrient concentrations have not had significant eutrophic effects in the estuary. As a benchmark for nutrient levels in the Delaware Estuary, it is helpful to look at corresponding levels in the Chesapeake Bay, where eutrophication has been a major concern triggering regulatory action. C.F. Cerco and T. Cole, who developed a three-dimensional eutrophication model for the Chesapeake, observed chlorophyll-a values between 10 and 25 mg/l nitrate, nitrite values between 0.0 and 0.75 mg/l and total phosphorous values between 3.5 to 16 mg/l (Cerco & Cole, 1993). In the Delaware Estuary, the mean chlorophyll-a value is similar, as are mean nitrite values. Mean nitrate values, with exceptions at the top and bottom of the estuary, are somewhat higher than in the Chesapeake Bay; and total phosphorous values are considerably lower, ranging from 0.00 to 0.97 mg/l. Again, no eutrophic effects are noted anywhere in the Delaware Estuary.

3.4.1 Range of Nutrient and Pigment Values

Nitrogen (NO3): The highest mean values in the lower Delaware River for nitrate-nitrogen are located around the New Castle and Cherry Island stations, with the lowest values located at either ends of the area, at the Mahon River and Fieldsboro stations. Average values are less than 0.2 mg/l. Minimum values are at 0.001 mg/l. Maximum levels are highest down in the bay at 1.9 mg/l **(see Figure 3.4-1)**.

Nitrite (NO2): The maximum value is 3.2 mg/l. at the Paulsboro, NJ station. Average values range between 0.1 and 2.0 mg/l **(See Figure 3.4-2)** and are highest between New Castle, DE and the Navy Yard.

Ammonia Nitrogen NH3+NH4-N: A maximum value of 0.3 mg/l was found at the Burlington Bristol Bridge Station **(See Figure 3.4-3)**. The mean values are between 0.05 and 0.15 mg/l. The larger mean values seem occur around the upper portion of the estuary north of the Burlington Bristol Bridge.

Total Phosphorous: Average levels of total P in the estuary are all less than 0.2 mg/l **(Figure 3-4.4)**. Maximum values range between 0.5 and 1.62 mg/l.

Orthophosphate: Average values of orthophosphate fall between 0.02 and 0.1 mg/l. Maximum values occurred in the upper portions of the bay (0.15 and 0.48 mg/l) **(see Figure 3.4-5).**

Chlorophyll a and Phaeophytin: The levels for these two photosynthetic pigments are presented in **Figures 3.4-6 and 3.4-7.** Chlorophyll levels and nutrients reported here were consistent with NJDEP monitoring results for this time period and the locations monitored by DRBC. However, it is important to note that measurements taken at the channel are not necessarily representative of the entire estuary. Differences exist between the levels of parameters such as dissolved oxygen and nutrients between the channel locations where DRBC monitors and other portions of the bay. For example, based on NJDEP monitoring data, chlorophyll *a* levels at the channel average around 6 µg/L whereas non-channel stations average around 9 µg/L. Also, nitrate levels tend to be higher at channel stations than at non-channel stations. Overall variability of the data at the channel tends to be much less that at more inshore locations. This is especially true in the lower portion of the bay (personal communication - Robert Connell, NJDEP).

3.4.2 Depth Related Effects on Nutrient Levels

Depth related data for nutrients during the report period was collected in 1997 during the MAIA program and in 2000 through 2003 during the NCA Program. These data were collected once at each of the 92 stations in the Delaware Estuary in 1997 and at 35 stations at each of the other years. The programs sampled bottom, mid and surface levels for different nutrient parameters. The results of this data set suggest that the Delaware River is a well mixed body of water, with the surface and bottom nutrient levels generally similar. **Figures 3.4-8 A-C** depict NCA data for the fall 2000 period, other years show a similar pattern.

4.0 TOXICS

4.1 PCBS

In 1996, the *Comprehensive Conservation and Management Plan for the Delaware River Estuary* (CCMP) identified PCBs as a pollutant of concern. Pennsylvania, New Jersey, and Delaware have all issued broad fish consumption advisories based upon PCB contamination in fish tissue to a lesser degree, contamination by chlordane and the chlorinated pesticides DDT and its metabolites DDE and DDD (DRBC 1998A).

Polychlorinated biphenyls (PCBs) are present in the environment in various media including air, water, and sediment. While the manufacture of PCBs was essentially banned in the late 1970's, they continue to be dispersed in the environment by human activity. They enter the atmosphere as a gas, spill into soils and waterways, and lodge in sediments. PCBs can also be generated as a byproduct by some industrial processes. The states of Delaware, New Jersey, and Pennsylvania have listed the Delaware Estuary as impaired due to elevated levels of PCBs in the tissue of fish caught in this portion of the Delaware River. This required the development of TMDLs for an 85-mile reach of the estuary (Santoro et al, 2004). A TMDL is the maxiumum amount of the pollutant that the estuary, lake, or river can receive and still attain the water quality standards.

On behalf of the states of Delaware, New Jersey and Pennsylvania, and in cooperation with the DRBC, the USEPA Regions II and III established TMDLs for PCBs in the Delaware River Estuary in 2003. EPA establishes these TMDLs in order to achieve and maintain the applicable water quality criteria for PCBs designed to protect human health from the carcinogenic effects of eating contaminated fish now found in the Delaware Estuary. In accordance with Section 303(d) of the Clean Water Act (CWA) and its implementing regulations, these TMDLs provide allocations to point sources (WLA) discharging PCBs as well as allocations to nonpoint sources (LA) of PCBs, and an explicit margin of safety (MOS) to account for uncertainties. The TMDL report and its appendices set forth the basis for these TMDLs and allocations and discusses follow up strategies that will be necessary to achieve substantial reductions of PCBs. EPA will continue to work with the Commission and the States to develop enhanced Stage 2 PCB TMDLs based on information to be collected and analyzed over the next several years. While EPA acknowledges that implementation of the TMDLs will be difficult and may take decades to fully achieve, the establishment of these TMDLs sets forth a framework and specific goals to protect human health from the effects of PCB pollution and restore the Delaware River to safe levels.

In addition to the human health risks associated with consumption of PCB-contaminated fish, PCBs pose an ecological risk to aquatic biota, particularly sediment-dwelling organisms. A study performed for the Delaware Estuary Program (Costa and Sauer, 1994) found that PCBs are far more widespread in sediments than was previously believed. PCB levels in sediments exceeded the no-observable-effects level (NOEL) at 14 of 16 stations sampled, with the highest concentrations detected between Chester, PA and Trenton, NJ. Importantly, these 16 stations were located in non-channel shoal areas, which comprise a far greater total area than the channel and are recognized as an important ecological habitat (DRBC 1998A). The high PCB levels found in non-channel areas, the extent of these areas, and the food web interactions known to exist in them serve to reaffirm the significance of the estuary PCB problem. More recent sampling performed by the USACOE in connection with the proposed "main channel deepening" project also revealed the presence of PCBs in main channel sediment samples, although at significantly lower levels than in adjacent shoal samples (Burton, 1997). The lack of comprehensive and reliable information concerning the sources of PCBs in the estuary and their transport pathways has hampered mitigation of the estuary PCB problem. A 1998 study by the DRBC began to address this critical gap in information (DRBC 1998A). **Figure 4.1-1** depicts the current PCB monitoring programs and locations in the Delaware Estuary that were initiated by DRBC during the report period.

4.1-1 Air Monitoring for PCBs in the Delaware Estuary

A study to quantify the concentration of polychlorinated biphenyls (PCBs) in the air and the flux of PCBs between the Estuary waters and the air were conducted during 2001-2003 by Rutgers University and the DRBC.

The study objectives included establishing and operating three atmospheric monitoring sites for PCBs at Lums Pond Delaware; Northeast Airport, Pennsylvania; and Swarthmore, Pennsylvania. These sites were used to quantify gaseous and particulate PCBs in the Delaware Estuary, and to identify and quantify regional and background sources.

The air monitoring stations were monitored in accordance with the protocols established for the New Jersey Atmospheric Deposition Network. The three stations identified above complement the existing three stations located in the New Jersey portion of the Delaware estuary and are identified in **Figure 4.1-1 and 4.1-2**. Station selection was based on identifying the regional signals of PCB pollution by locating monitoring sites in urban and suburban areas in the upwind and downwind direction of the prevailing weather patterns. Data from all stations have provided long-term spatial and temporal information on the concentration and seasonal variability of PCBs in the Delaware estuary. Approximately 200 samples have been collected and analyzed for particulate and dissolved PCBs during the study period and the results have been used to inform the DRBC's PCB modeling efforts.

Air-water exchange measurements have been conducted over a one year period during the study period at five different locations. Net fluxes varied by location but generally the net flux was from the water to the air. Results of the water air flux study of PCBs have provided vital information for the modeling of PCBs in the Delaware Estuary.

<u>Air Deposition Survey</u>
Concentrations of PCBs in the air were measured in the particulate and dissolved phases using a high volume air sampler. Quartz fiber filters were used to capture particulate matter and polyurethane foam plugs were used to capture the dissolved phases. Analysis was conducted using a gas chromatography equipped with a nickel electron capture detector. The resulting detection limits were on the order of < 1 pg/l. Typically, less than 10% of the total

atmospheric PCB concentrations are found in the particulate phase. Furthermore, gas phase concentration can vary by up to two orders of magnitude from site to site, with the highest concentrations occurring in the urbanized area of NE Airport and Swarthmore, Pennsylvania. The highest PCB concentrations ever reported have been observed at the Camden location. A graphical representation of gaseous PCB concentrations at the three monitoring stations is provided in **Figure 4.1-3**.

Air-Water Flux Survey
Five surveys were conducted in the Delaware Estuary in order to quantify the air-water exchange fluxes of PCBs. These surveys occurred during all four seasons at five locations within the estuary. These surveys were conduced concurrently with the air deposition study. Air samples were collected at the same location as water samples and analyzed in the same manner. The concentrations measured over the water are in good agreement with those measured on land for those dates where sampling coincided. The typical net flux for all four sampling locations for all five cruises is from the water to the air.

The results of the study show that PCB concentrations vary by orders of magnitude between urbanized and rural areas, suggesting existing sources of PCBs are volatilizing to the atmosphere. Concentrations recorded in some urbanized areas also suggest that the PCBs in the air may ultimately be a source of loadings to the estuary for those locations.

4.1-2 Stream flow monitoring for PCBs

An analysis of stream flow for the Delaware River at Trenton, and the Schuylkill River at Philadelphia was conducted by DRBC in support of the PCB TMDL development for the Delaware Estuary. The study objective was to identify a twelve month period that represented the long-term flow conditions at the Delaware River at Trenton and the Schuylkill River at Philadelphia.

The DRBC constructed hydrodynamic and water quality models to determine the transport and fate of PCBs in the Estuary. A decadal scale modeling simulation was required as a part of the model calibration and TMDL development. It was determined to use a one year period to represent hydrologic conditions and cycle the one year period to conduct long-term simulations. The Delaware River at Trenton and the Schuylkill River at Philadelphia together represent over 70 percent of stream inflows into the Delaware Estuary. Therefore, in order to accurately represent the transport of PCBs in the estuary, it was necessary to select flow regimes that represented long-term flow conditions. Representativeness was determined by comparing flow statistics from the calibration period to long-term flow statistics. Stream flow information from the USGS gage at Trenton, (USGS gage 01463500) for the period of record 1912-present and for the USGS gage at Philadelphia (USGS gage 01474500) for the period of record 1934-present was used in this analysis. The following approach was utilized in selection of a 12 month period to be used in modeling runs:

1. Data for the period of record for each gage was ranked and percentile graphs were constructed.

2. Twelve month rolling bin increments for the calibration period beginning in September 2001 were ranked and graphically compared to the historical data.

Graphical representations are provided in **Figures 4.1-4 and 4.1-5** for the Schuylkill and Delaware Rivers respectively. Both graphs represent the flows in cubic feet per second vs. the percentile for that flow for the long-term and twelve month periods. The February 2002 to January 2003 period of record from the nineteen month calibration was selected as the best match to the long-term flow data for the Delaware River at Trenton and the Schuylkill River at Philadelphia. This period was then used in decadal scale model runs.

4.1.3 Ambient Water Body PCBs

The PCB modeling effort supports the establishment of four pollution budgets known as TMDLs, one for each management zone that set the maximum amount of a specific pollutant in this case PCBs that can be introduced into the river. The EPA has classified PCB as a probable human carcinogen. Although their production was banned in the United States in the late 1970s, substantial amounts of the toxic substance remain in the environment. PCBs are still found in thousands of industrial and commercial applications, including electrical transformers, and in paint, plastic, and rubber products. They accumulate in river sediment and soil, and in the fatty tissue of fish. Human exposure results from eating those fish.

The PCB TMDL addresses all potential sources of PCBs, including storm water runoff point sources, tributaries, and runoff from Superfund sites, which are the major contributor of PCBs into the river. EPA, the three states, and other stakeholders are in the process of developing pollution reduction strategies to address these major sources.

The point sources include 142 permitted discharges from municipal waste water and industrial facilities along the river that were identified in Stage 1. These sources will be required to identify how and where the PCBs were located before they are discharged to the Delaware River.

To support development of the Delaware Estuary PCB Homolog Water Quality Model, accurate measurements of PCB concentrations in the Estuary were required. Ambient water samples were collected from the mainstem Delaware Estuary for the analysis of PCB concentrations at low, high and intermediate flows in the portions of the Delaware Estuary listed for TMDL development. Fifteen main stem channel sites in the tidal river were sampled for a total of seven sampling events, and four surveys in Delaware Bay.

PCB (total) data are presented in Figure 4.1-6. This figure indicates that in general higher concentrations of PCB are observed in low flow conditions. As the river flow increases the concentration of PCB decreases. In the lower flow sampling events, the concentration of PCB shows a pattern of elevated PCB between river miles 80 and 107 indicating PCB loadings in the urbanized areas of the river. A similar pattern of PCB distribution is not observed in the higher flow sampling events. In the higher flow sampling events, PCB concentrations are lower and more evenly distributed over the sample area probably from dilution of PCB during high flow conditions.

4.1.4 Fish Tissue Levels

The states of Delaware, New Jersey, and Pennsylvania have identified the Delaware Estuary as impaired on their respective lists pursuant to Section 303(d) of the CWA. The States identified the impairments based on their findings of elevated levels of polychlorinated biphenyls (PCBs) in the tissue of fish caught in this portion of the Delaware River. The listing was based upon the failure to attain one of the estuary's primary designated uses – fishable waters and the inherent protection of human health from consumption of unsafe fish. When water quality standards, including a numeric criterion and a designated use, are not attained despite the technology-based control of industrial and municipal wastewater (point sources), the Clean Water Act requires that the impaired water be identified on the state's Section 303 list of impaired waters and that a total maximum daily load (TMDL) is developed.

Figure 4.1-7 presents analytical results for the white perch and channel catfish samples collected in the Delaware River. For each sampling location, the total concentration based on the sum of 99 PCB congeners normalized to lipid percent in the tissue sample is shown. These fish exhibited concentrations between 270 and 910 ug/g lipd weights by lipid percent with the highest concentrations observed in fish collected near the C&D Canal and Crosswicks Creek. A PCB concentration of 3.33 ug/g lipd (the equivalent for fish tissue of the established water quality standard) is projected to result in one additional cancer case per million people exposed through consumption of one-half pound of fish every 35 days.

Metals

Figure 4.1-8 shows the metals concentrations in tissues of white perch and channel catfish **(Figure 4.1-9)** collected in several locations in the Estuary. Elevated levels in white perch exist for arsenic (6.5-10 ppm wet wt) and to a lesser extent copper (1-2ppm wet wt.). A similar pattern exists for channel catfish which contained arsenic levels of 4-5.5 ppm wet wt. and copper levels from 0.25-1.3 ppm wet wt as well as levels of nickel (0.1-1.4 ppm wet wt.).

4.2 Sediment Toxicity

As part of the 2000 National Coastal Assessment, amphipods (*Ampelisca abdita)* were exposed to sediment samples from the Delaware Estuary for 10 days under static conditions. The survival of the amphipods in estuarine sediment samples was compared to survival in control sediments. If the sample mean survival was less than 20% of the control survival, the sediment was reported as toxic (NCA, 2000). Based on the National Coastal Assessment Report, two out of twenty-six sites are shown in **Figure 4.2-1** as toxic. One toxic site is in the Maurice River and the other site is in the Delaware Bay north of the Broadkill River. The National Coastal Report also lists the Maurice River site as having high sediment contamination and a poor benthic index providing a strong weight of evidence for sediment toxicity. The Delaware Bay toxic site is reported to have a poor benthic index based on the contaminants measured, but is not reported to have high sediment contamination. It should be noted that sediment toxicity data are absent for the 2000 National Coastal Assessment locations in Zones 2 and 3 where sediment toxicity has previously been measured (AD Little DELEP Report #94-08 and Santoro, 2000).

5.0 LIVING RESOURCES

More than 200 species of migrant and resident finfish species have been identified in the Delaware Estuary. Some of the prevalent species include sharks, skates, sturgeon, American eel, blueback herring, Atlantic menhaden, alewife, American shad, striped bass, bluefish, weakfish, and flounder. Currently, some 31 finfish species are caught commercially in the Delaware Estuary, but the commercial fishing industry is much smaller than the recreational fishing industry.

The Delaware Estuary is internationally recognized for its importance as a stopover for migrating birds. The living resources monitored in the Delaware River and Delaware Bay include horseshoe crab, blue crab, and six species of finfish – American shad, weakfish, striped bass, Atlantic sturgeon, shortnose sturgeon, and American eel. The Estuary is the home of the world's largest population of horseshoe crabs. The blood of the horseshoe crab is used to help detect minute amounts of bacterial toxins associated with bacterial diseases, fever, shock, and death of humans. The annual late-spring mating and nesting of the horseshoe crab is an inspiring spectacle for avid bird watchers who travel to the bay shore to gaze at hundreds of thousands of red knots, ruddy turnstones, sanderlings, semipalmated sandpipers, and other migratory birds feasting on horseshoe crab eggs.

5.1 Oysters

The oyster fishery is managed in New Jersey jointly by NJDEP (regulation and monitoring), Haskin Shellfish Research Laboratory (HSRL) (science) and the Delaware Bay Section of the Shell Fisheries Council (industry liaison). The process starts in the fall with a stock assessment survey conducted by the HSRL and a meeting of the Oyster Industry Science Steering Committee (a Fisheries Council subcommittee) to set the terms of reference for the assessment. HSRL scientists conduct analyses pursuant to these terms of reference and present them to an external review committee, the Stock Assessment Review Committee or SARC at a February Stock Assessment Workshop or SAW. The SARC drafts a report based on the information presented to them that includes sections on the State of the Stock and Management Advice. This report is provided to the NJDEP and Council who use the information therein to develop the regulations for the coming year, including the allocation.

The assessment is based on a biological reference point termed the constant abundance reference point that sets the management goal. This goal is no net reduction in market-size abundance. A fisheries model uses the survey data and the reference point to generate estimates of allowable harvest to meet the goal. The approach has been successful in permitting (a) rebuilding of the stock after disease outbreaks and (b) sustainability of the stock by minimizing the chance of over harvesting of a population subject to wide swings in natural mortality due to disease. The limitation on harvest today is the limitation on recruitment. The recruitment rate sets the harvest level, in essence, because the constant abundance reference point permits harvest only of the surplus production not required to replace those animals lost to natural mortality each year.

As a consequence, increased recruitment permits increased harvests. Implementing a recruitment enhancement program, based for example on shell planting and transplant of spat, will directly increase harvest by increasing surplus production without jeopardizing the sustainability of the resource (Personal communication Eric Powell).

This section summarizes the Delaware Estuary oyster seedbed sampling data from New Jersey and Delaware. **Figure 5.1-1** shows the approximate oyster abundance per bushel in Delaware Bay. Sampling in Delaware Bay takes place in the fall of each year, typically in late October, using an industry oyster dredge boat in New Jersey and the state survey boat in Delaware. While the data collected by New Jersey and Delaware are comparable, there are some differences in methodology. The sample locations for both states are based on a grid system for each bed. New Jersey uses a stratified random selection of grids within the bed while Delaware uses fixed stations. In New Jersey three one minute dredge hauls are taken in each grid and a composite bushel of material (about 1/3 from each haul) is retained. Each dredge haul is calibrated by sampling the length of the haul with a GPS system that records the position at six second intervals. The bushels of material brought up by the dredge are estimated from the volume in a calibrated hopper. In Delaware, the dredge tows are not timed, and a one bushel sample is arbitrarily selected from the material brought up in the dredge in both states. In both New Jersey and Delaware, bushels of material are sorted into volumes of oysters, cultch, and debris. Counts are made of live oysters, boxes (dead oysters), live spat, dead spat and ancillary information is collected on presence of oyster drills, *Stylochus*, crabs, sponges, barnacles, and black shell. All live and dead oysters (> 20 mm) are measured. Subsamples are set aside for condition index (Dry meat weight/oyster height), and pathology (*Perkinsus marinus*, dermo; and *Haplosporidium nelsoni* – MSX), and 3 quarts of cultch are set aside to provide a counting control for potentially missed spat.

The variability associated with the estuarine gradient makes it difficult to statistically show year to year difference in abundance, spat, disease levels, or mortality. Trends are readily apparent when several years of data are displayed (**See Figure 5.1-2**).

In general, Delaware's data are more variable **(See Figure 5.1-2).** This reflects the smaller number of beds being sampled and the more restricted areal extent of the seed beds on the Delaware side of the Bay. The numbers of oysters per bushel in New Jersey have remained in the 100 to 175 range since 1990, and are currently at the low end of that range (**Figure 5.1-3**).

Delaware oyster abundance ranged from 350 oysters per bushel to slightly less than 100, and recently these resources have shown a substantial drop to the low end of the range (**Figure 5.1-3**). Spat abundance throughout the system appears to be more tightly coupled than overall oyster abundance (**Figure 5.1-2**). The three consecutive years of modest set in the late 1990s have provided the bulk of the oyster resources that are present in the system (**Figure 5.1-4**).

The four year period of very low spat abundance from 2000 to 2003 has caused a significant loss of oyster resources in the higher salinity parts of the seed beds. A continuation of this trend will certainly yield continued reduction in oyster abundance

throughout the Delaware Estuary. Historically in the Delaware Estuary, oysters were removed from the seed beds and planted on leased grounds farther down bay. This practice has caused some difficulty in terminology in that the oysters removed (harvested) from the seed beds were differentiated from those brought to shore and sold (landed). To be clear, we have simply used oysters removed from the seed beds (**Figure 5.1-3**).

The data in this chart are not comparable because the New Jersey data for 1990, 1991 and 1995 reflect oysters of all sizes removed for planting, but beginning in 1996 a new management scheme only allowed removal of market size oysters from the seed beds. Blanks in the data reflect periods when the seed beds were closed to harvest.

The dominant force controlling oyster numbers in the 1990's and early 2000's has been the appearance of the oyster disease dermo and its proliferation into epizootic status. While this parasite has been reported from the Delaware Bay system in earlier years, it never caused serious levels of mortality. Two hypotheses have been proposed for this increasing mortality. The first is that warmer winters allow more parasites to survive. The second is there has been a change in the genetics of the oyster mortality and dermo levels parasite.

At present, there is no way to determine if the change is due to one, both or some combination of the two. The resurgence of this parasite resulted in the change in management strategies in both New Jersey and Delaware. The combination of heavy dermo losses (exceeding 50% annually on many of the higher salinity seed beds), combined with a historically unique 4 years of poor recruitment has seriously depleted oyster stocks on all higher salinity seed beds. There are currently significant numbers of oysters on the upper bay seed beds, but these are mostly in the larger size categories and natural mortality will begin to reduce these numbers through time. The major concern at present is the lack of recruitment to replace these older oysters.

5.2 Horseshoe Crab

In October 1998, the Atlantic States Marine Fisheries Commission (ASMFC) Horseshoe Crab Management Board approved an *Interstate Fishery Management Plan for Horseshoe Crab* (Interstate FMP). The objective of the Interstate Plan is to compile an accurate count of the annual horseshoe crab harvest for each of seventeen Atlantic states, and to use these data to develop a coast-wide cap on horseshoe crab landings. The ASMFC Board intended for the cap to be implemented in the year 2000.

The interstate FMP requires the seventeen Atlantic states to submit compliance reports containing steps for the plans implementation. The ASMFC Technical Committee reviewed these reports and presented their recommendations to the Management Board on March 17, 1999. Delaware's and New Jersey's reports were among only five to be approved by the ASMFC Management Board from among the seventeen submitted. Many of the plans were rejected because they failed to account for collection of the crabs for personal use, and thus, in the Board's view, could not demonstrate that an accurate count of landings would be made. Because so many of the states' implementation plans were deficient, the deadline for submission of the implementation plans was extended, postponing the likely date of implementation of a cap on landings.

In order to implement the interstate FMP, most of the states are developing statutes or regulations which will require an accurate count of horseshoe crab landings. To further the goal of accurate monitoring, the ASMFC Technical Committee coordinated a series of workshops, which resulted in the design of a statistically valid spawner beach and egg count survey that was implemented in Spring 1999. A coast-wide tagging program was also developed, to be coordinated by the USF&WS and implemented by the biomedical industry. Evaluation of the post-release mortality of horseshoe crabs used by the industry has begun. Additionally, a research proposal was approved to examine the genetic structure of the Atlantic coast horseshoe crab population. Genetic information on the crabs will be useful in determining if geographic sub-populations exist and if regional management is possible (ASMFC, 1999).

The FMP contains a monitoring program aimed at providing the necessary data to facilitate future management decisions, and maintains horseshoe crab harvest control measures recently put in place in New Jersey, Delaware, and Maryland to protect horseshoe crab spawning within and adjacent to the Delaware Bay. The FMP directed the Management Board to implement a cap on horseshoe crab bait landings in 2000, and recommended that the Secretary of Commerce address and initiate controls over the harvest and use of horseshoe crabs in federal waters. The Management Board proceeded with developing a coastwide cap on horseshoe crab bait landings to control the harvest and fulfill the goals and objectives of the FMP. Several management options were identified by the Management Board and incorporated into a Public Information Document, which was made available to the public in December 1999, and presented at state public hearings in January 2000. On February 9, 2000 the Management Board reviewed input from the Technical Committee, Advisory Panel, and public, and approved Addendum 1. Addendum 1 of the Interstate Fishery Management Plan for Horseshoe Crab sets forth changes to the harvest level threshold for horseshoe crab bait fisheries and establishes *de minimis* criteria for those states with a limited horseshoe crab bait fishery. The Management Board established the following harvest level for horseshoe crab bait fisheries:

- A state-by-state cap on the landings of horseshoe crab for bait landings at 25 percent below the reference period landings by May 1, 2000. Individual state horseshoe crab bait fisheries would be closed once their state's cap is reached [1]

The Management Board also recommended the following management measure to provide further protection to the Delaware Bay horseshoe crab population, recognizing its importance to migratory shorebirds:

- Encourage states with more restrictive harvest levels to maintain those regulations, until such time that the state comes forward with a plan for adjusting their harvest that has been reviewed by the Technical Committee and approved by the Management Board.
- Request that the NMFS to close the harvest of horseshoe crabs in Federal waters

[1] The harvest reduction of 25% below the reference period landings would be assessted for the entire year (Jan.-Dec). The Board Would review over the harvest (i.e., overages by states in any particular year and would substract the overages from subsequent harvest thresholds.

within a 30 nautical mile radius of the mouth of Delaware Bay. The taking of horseshoe crabs for any purpose, including biomedical, would be prohibited in this area closure.

- Request that the NMFS should prohibit the transfer of horseshoe crabs at sea in federal waters.

The ASMFC Interstate Fisheries Management Fisheries Program Charter defines *de minimis* as "a situation in which, under existing condition of the stock and scope of the fishery, conservation, and enforcement actions taken by an individual state would be expected to contribute insignificantly to a coastwide conservation program required by a Fishery Management Plan or amendment."

States may apply for *de minimis* status if, for the last two years, their combined average horseshoe crab bait landings (by numbers) constitute less than one percent of coastwide horseshoe crab bait landings for the same two-year period (for 2000, Reference Period Landings would be used and for 2001, the average of reference period landings and 2000 landings would be used). States may petition the Board at any time for *de minimis* status, if their fishery falls below the threshold level. Once *de minimis* status is granted, designated States must submit annual reports to the Board justifying the continuance of *de minimis* status. States that qualify for *de minimis* status are not required to implement any horseshoe crab harvest restriction measures, but are required to implement components A, B, E and F of the monitoring program (Section 3.5 of the FMP). Since *de minimis* states are exempt from a harvest cap, there is potential for horseshoe crab landings to shift to *de minimis* states and become substantial, before adequate action can be taken. To control shifts in horseshoe crab landings, *de minimis* states are encouraged to implement one of the following management measures:

- Close the respective horseshoe crab bait fishery when landings exceed the *de minimis* threshold;

- Establish a state horseshoe crab landing permit, making it only available to individuals with a history of landing horseshoe crabs in that state; or

- Establish a maximum daily harvest limit of up to 25 horseshoe crabs per person per day. States which implement this measure can be relieved of mandatory monthly reporting, but must report all horseshoe crabs harvests on an annual basis.

This addendum also requires that all state programs include adequate law enforcement capabilities for successfully implementing the jurisdiction's horseshoe crab regulations. The adequacy of a state's enforcement activity will be measured by annual reports to the ASMFC Law Enforcement Committee and the PRT.

Horseshoe Crab Status

According to Swan, et al. (2003) the 2002 year's estimate of the visiting population of horseshoe crab was higher than the previous two years of 2000 and 2001, an increase attributed to greater numbers observed spawning along the upper bay beaches of the New Jersey shoreline. This was undertaken by trained volunteers recording the numbers of crabs on 13 beaches in Delaware and 10 beaches in New Jersey. The counts were performed during night hours enumerating male and female animals along the water's edge. In 2002, the spawning activity was greatest on May 28th, 2 days after the full moon, with 333,553 spawning individuals estimated. Delaware spawners were calculated to be 203,389 and New Jersey animals were 130,164 for this date. Compared to the past two years, this estimate surpassed 2001's estimate of 216,929 individuals and 2000's estimate of 272,770. New Jersey's peak estimate of 130,164 individuals on May 28th was higher than both the 2000 and 2001 estimates.

Consistent with previous years, the shoreline of Delaware supported more spawning activity than the New Jersey side. Spawning numbers were most numerous during the May survey dates in both New Jersey and Delaware, almost three times the June spawning numbers.

Swan et al (2003) noted that the 2002 peak spawning estimate was a very welcome sight with approximately 30% more spawners than the 2001 estimate and 20% more than in 2000.

A summary of the volunteer Horseshoe Crab Counts on the spawning beaches in New Jersey and Delaware are presented over the period 1996 to 2003 in **Figure 5.2-1.** As reported by Swan, et al (2003), after viewing the 2002 peak spawning estimate, which is an indication of the current horseshoe crab plight, they suggests that t**he restrictive measures introduced in the Delaware Bay region on harvesting, the implementation of the Carl N. Shuster Jr. Horseshoe Crab Reserve (CNSJrHSCR) and the utilization of bait bags seem to be benefiting the horseshoe crab. However, the increase is not substantial enough to warrant any less restrictive measures in the management of the species (Swan et al, 2003).**

The State-specific spawning activity of horseshoe Crabs was reported by Smith and Bennett (2004). Over the 1999 to 2003 period in the states of Delaware and New Jersey the levels show relative stability in spawning activity and appear to be somewhat offsetting **(Figure 5.2-2)**. The change in spawning activity in New Jersey is slight and positive, although not significantly so (slope = 0.02, SE = 0.040, P = 0.73), and in Delaware the change is negative, although again not significantly so (slope = -0.06, SE = 0.025, P = 0.12).

As reported by Smith and Bennett (2004), spawning has tended to peak in late-May, although there has been considerable year-to-year variation in the timing of spawning activity. The peak Horseshoe Crab spawning in 2003 occurred later in the year and the percent of spawning in May was lower than in previous years. In 2003, there was very little spawning until the end of May. **Smith and Bennett (2004) concluded that spawning activity in Delaware Bay over the past 5 years has been either stable or declining at a rate less than 8% per year. Spawning activity appears more stable in New Jersey than in Delaware.** Patterns of decline in spawning activity on Delaware beaches show up when examining data from beaches individually and when data are summarized statewide.

5.3 Blue Claw Crab

The Blue crab (*Callinectes sapidus*) inhabits near-shore coastal and estuarine habitats throughout the western Atlantic, Caribbean, and as far south as Ecuador. In 2003, almost 7 million pounds of blue crab was landed in Delaware Bay (**Figure 5.3-1**). Despite the fact that Delaware Bay is near the northern extremity of its distribution, blue crab catches produce the largest dockside value of any fisheries resource in the bay. Cole (1998) estimated that commercial landings of blue crab in Delaware from 1988-1995 averaged 4.5 million pounds and produced an annual dockside value of $2.5 million. Commercial landings of blue crab in Delaware over the past ten years have averaged 4.6 million pounds, with an annual estimated value of $4.3 million dollars. With an increasing demand for crab meat, coupled with declines of harvests in the Chesapeake Bay stock, effort on the Delaware Bay stock has increased markedly since the mid-1980's (Cole 1998).

In 1999, amid raised concerns about declines in Delaware Bay blue crab landings (Cole 1998), the Delaware Bay Blue Crab Fishery Management Plan (FMP) was jointly developed by the State of Delaware Division of Fish and Wildlife and the State of New Jersey Division of Fish, Game, and Wildlife. This document was submitted to the Delaware State Legislature (Delaware Division of Fish and Wildlife 1999). The goal of the FMP is to conserve the bay-wide blue crab stock, insure the long-term sustainability of the resource, and provide fair allocation among the commercial and recreational user groups from New Jersey and Delaware. This document put forward the following ten objectives:

1) Maintain limited entry in the commercial fishery to prevent overcapitalization.
2) Until additional information is available to demonstrate otherwise, maintain bay-wide fishery yields within the ranges of 6.8 to 14.5 million lbs.
3) Complete and continually update a stock assessment based on the best available scientific information and computer models available.
4) Improve the knowledge of early life history stages for blue crabs (including environmental factors influencing growth and survival).
5) Evaluate the biological and socioeconomic effects of gear controls to discards and by-catch.
6) Improve fisheries dependent data collection.
7) Enhance inter-state resource management efforts and data collection protocols.
8) Exchange biological and fisheries-related information between Delaware and New Jersey on a regular/continuing basis.
9) Coordinate data analysis and establish peer review teams to review stock assessment analyses.
10) Implement comprehensive, complementary management approaches based on cooperative, synchronized efforts from New Jersey and Delaware natural resource agencies.

The FMP recommends that both Delaware and New Jersey review their mandatory harvest reports each year in order to determine how many dredge and pot licenses have not been fished within the previous years. License holders who have not reported within the preceding three-year period would not be permitted to renew their license. This action would help prevent any increases in fishing effort from the activation of latent licenses. The FMP also supports the use of cull rings to increase escapement and thus survival of juvenile blue crabs. At present, the plan recommends voluntary use of cull rings. Continued mandatory use of turtle excluder devices in New Jersey and the tidal streams and inland bays of Delaware is encouraged.

The Division of Fish and Wildlife was tasked with providing an analysis of available blue crab data, assessment of the stock, and the estimation of biological reference points and fishery management benchmarks in support of the FMP. This assessment was completed in 1999 and has been updated annually (Helser and Kahn 1999, Helser 2000, Helser and Kahn 2001, Bancroft and Kahn 2002, Kahn 2003).

The bi-state Delaware Bay blue crabs population is presently treated as two separate management units, with New Jersey and Delaware implementing separate fishery regulations. Because the larval stage is transported to the coastal shelf before re-entering the Bay to settle, mixing with other stocks in the region may occur at this stage. Kahn et al. (1998) discussed the hypothesis that the Delaware Bay stock should be considered part of a metapopulation. Considering the significant stock-recruitment relationship for Delaware Bay, the stock is probably the primary source of its own recruits.

The blue crab stock assessment for 1999 (Helser and Kahn, 1999) represented the first successful attempt at deriving estimates of stock sizes and fishing mortality rates, and at estimating biological reference points from which a fishing target and overfishing threshold can be derived for the Delaware Bay blue crab stock. The blue crab stock assessment for 2000 (Helser 2000) extended this framework by incorporating an uncertainty analysis. These assessments served as the basis for the development of the Delaware Bay Blue Crab Fishery Management Plan which was submitted to both Delaware and New Jersey (Delaware Division of Fish and Wildlife, 1999). There is currently no accepted method of aging blue crab; therefore an age-structured assessment could not be conducted. Instead, the catch-survey model was employed, or modified-Delury model, which models the population using two stages (Collie and Sissenwine, 1983; Conser and Idoine, 1992). Auxiliary information of relative abundance of the size groups from research surveys and annual catches are integrated into a single model framework to estimate stock sizes, stock biomass, and fishing mortality rates. Overfishing definitions based on biological reference points were developed from other methods such as yield and SSB-per-recruit analyses and standard spawning stock-recruitment plots. A mixed Monte Carlo-Bootstrap procedure was developed to incorporate uncertainty in the terminal year fishing mortality rates and the biological reference points to which they are compared (Helser and Kahn 2001; Helser et al 2002). A probabilistic framework was then used to evaluate decisions regarding the overfishing status of the Delaware Bay blue crab resource. Bancroft and Kahn (2002) updated the assessment through 2001. Kahn (2003) updated the assessment through 2002.

In summary, the assessment consists of examination of landings, fishing effort, and survey indices of relative abundance. A catch-survey model, or modified DeLury model, was employed to estimate the catchability coefficient used to convert survey indices to estimates of absolute abundance for the period 1979-2003. These estimates were combined with catch data to estimate total mortality and instantaneous fishing mortality (F) annually from 1979-2002. The assessment includes an update of the stock-recruitment model with additional data for 2002 and recovered data for 1979 and 1980.

The catch-survey model fit the Delaware Bay blue crab data fairly well; NLLS estimates of recruit and fully-recruited stock sizes were relatively precise (CV range: 30-48%). The NLLS CV for the catchability coefficient was 25%, indicating a relatively precise fit. Stock sizes were estimated for January 1. Final estimates of recruit stock size in the last 3 years were equal to the 1979-2002 average of 95 million until 2003, when the estimate dropped to 50.6 million. Estimated fully-recruited stock sizes ranged from 6 to 49 million with an average of 22 million crabs from 1979-2002 **(Table 5.3-1)**. **Over the last 3 years, annual estimates of fully-recruited stock size ranged from 14 million to 28 million, with the estimate for January 1, 2003 dropping to 14 million, prior to the winterkill of 2003. Estimated biomass of fully-recruited crabs (exploitable biomass) ranged from 4 million to 23 million pounds, with an average biomass of 11 million pounds from 1979-2003. While exploitable biomass has trended upward over time since 1979, the last five years have shown a declining trend since a peak in 1998. For 2003, the estimate was well below the long-term average at 5.9 million pounds, prior to the winterkill, which certainly reduced both abundance and biomass substantially.**

Fishing mortality rates on fully-recruited blue crabs ranged from 0.23 to 1.18, with an average of 0.73 over the 1979-2002 period. Average F in recent years (2000-2002) for fully-recruited blue crabs was 0.62 and the F for 2002 was estimated at 1.18, the highest value in the time series. Recent estimates of spawning stock biomass, prior to 2003, have been moderate. These are levels that on average should produce relatively high recruitment according to the Ricker stock-recruit model. However, recruitment to the fully-recruited stock has been moderate to low, due to environmental factors producing lowered survival (**Figure 5.3-2**).

The severe winter of 2003 inflicted heavy overwintering mortality on mature crabs, which, combined with harvest, resulted in a spawning stock biomass index of zero, for the fifth time during the 1978-2003 period. Based on past patterns of spawner-recruit data, this indicates a reduced probability of high levels of recruitment in the fall of 2003, although favorable environmental effects may mitigate the low levels of spawning biomass as occurred in 1996, when recruitment was relatively good despite a zero index of spawning biomass.

Currently in 2003, the winterkill and relatively low survival of recruits in 2002 have contributed to a stock reduction.

Biological reference points in Helser and Kahn (1999) were calculated from the Thompson and Bell model as: $F_{0.1} = 0.6$, $F_{MAX} = 1.0$, while F_{REP} calculated from SSB-per-recruit and SSB-Recruitment indices was 1.3. An appropriate overfishing threshold mortality rate is 1.3 (F_{REP}) and fishing mortality rates in excess of this value would increase the likelihood of jeopardizing the resource. The recent average fishing mortality rate is below $F_{MAX,}$ is equal to $F_{20\%}$ and is below the overfishing threshold mortality rate of F_{REP} =1.3. The $F_{2002} = 1.18$ exceeded all reference points except the overfishing threshold. Based on yield and SSB-per-recruit considerations, recent assessments recommended a fishing target somewhere between $F_{0.1} = 0.6$ and $F_{MAX} = 1.0$.

The assessment suggests that the Delaware Bay blue crab stock is being fished at a level that is sustainable in most years, with some years of quite high F that approach, but do not meet, the overfishing threshold. Therefore, it is recommended that increases in fishing effort should be avoided and consideration should be given to reducing fishing effort (Figures 5.3-3). Further, targeting of mature female crabs in the fishery, particularly when they are concentrated, should be discouraged, in order to protect the spawning stock. The 2003 YOY index is approximately equal to the long-term average. If it continues to remain at or below the long-term average, additional consideration should be given to protection of the spawning stock (**Figure 5.3-4, 5.3-5**).

5.4 American Shad

Monitoring programs for juvenile American shad are conducted annually throughout the Delaware River from Artificial Island to Milford, Pennsylvania, a distance of approximately 180 miles. All sampling programs document good recruitment of American shad.

Seining for juvenile American shad in the Delaware River was completed for 2003. A total of 16,657 shad were collected from four sites. At the most downstream site, Trenton: 1,157 (6.95%) shad were collected; Phillipsburg: 4,275 (25.66%) shad; Delaware Water Gap: 2,036 (12.22%) shad; Milford PA: 9,189 (55.17%) shad. The largest number of shad was collected during the month of August: 9,436 (56.64%) shad; September: 5,961 (35.79%) shad; October: 1,260 (7.57%) shad. The overall catch per seine equaled 347 shad which is the third highest ever recorded. It is well above the average of 215 shad per seine. Colder than normal spring water temperatures prolonged the spawning period, enabling more adult American shad to migrate farther upstream. This is evident in the highest numbers being collected at the Milford, PA site and the fact that the juvenile shad were smaller in size than previous years (Personal communication M. Boriek, NJDF&G).

As determined by hydroacoustic methods, an estimated 300,000 American shad returned to the Delaware River to spawn in 2003 indicating a decline of approximately 40 percent from the 2002 population **(Figure 5.4-1)**. The fluctuation in population over the report period likely reflects natural variation.

Figure 5.4-1 presents the catch per unit of effort (CPUE) from seining for juvenile American shad in the Delaware River above Trenton, for the time period 1991- 2003. The 1998 CPUE of approximately 60 is the lowest recorded since 1979. It is dramatically lower than the CPUE of 450 recorded two years earlier in 1996 and well below the CPUE of approximately 275 recorded in 1997. No explanation has yet been determined for the apparent decline in population. One theory is that improved water quality has allowed spawning to occur in the lower reaches of the river, resulting in fewer shad in the upper reaches where sampling has been undertaken. Anomalous events, such as weather patterns or "incidents at sea" could account for variability as well. The results could also be an artifact of sampling design or the product of a combination of factors. A Fisheries Technical Committee of the Delaware River

Basin Fish and Wildlife Management Cooperative, which includes representatives from New Jersey, Delaware, Pennsylvania and New York, has been established to focus on these questions and the overall strength of the resource. A discussion of the population estimates based upon hydroaccoustics is presented in **Appendix 12.3.**

5.5 Striped Bass

The population of striped bass in the Delaware River has experienced a remarkable recovery within the last decade, largely attributable to improved water quality and strict fishery management measures. The striped bass spawning stock in the river is monitored by both Delaware and Pennsylvania during the spring migration. Young-of-year recruitment surveys conducted by both New Jersey and Delaware show the resurgence in spawning success for the species**. Figure 5.5-1 a, b** presents the year class of striped bass in the Delaware River during the report period for recreational striped bass. Approximately 34 percent of individuals (both sexes) collected were five-year-old fish. The next largest class included 8-year-old fish (10.6 percent), followed by 4-year-old fish (9.7 percent), and 9-year-old fish (9.5 percent). The smallest numbers collected were 14- and 16-year-old fish (0.2 percent each), with no 15-year-old fish collected.

Striped bass were declared restored in the Chesapeake Bay since 1995. Abundance levels have been high since. However evidence has accumulated that the resident population, comprising primarily younger fish primarily through age 5, predominantly male, is affected by disease and a suboptimal forage base. A complex of mycobacterium species currently infects a significant portion of resident stripped bass. Infected bass may exhibit external lesions and have internal granuloma pathology. The condition factor or weight at length, may be lower than optimal. Young Atlantic Menhaden, a primary forage species for striped bass, have been at relatively low abundance for several years and have shown disease manifestations themselves in significant numbers, at least in some years. Current estimates of the coast wide Atlantic menhaden spawning stock are significantly lower than estimated abundance in the 1950s and early 1960s, when striped bass were last at high abundance levels. Recent tag-recapture data indicates that survival of resident striped bass has declined, yet tag-recapture estimates of fishing exploitation have not increased, suggesting that natural mortality has increased. (Dr. Desmond Kahn personal communication).

5.5.1 Status of Delaware Bay Stocks of Striped Bass

A coast-wide stock of striped bass is comprised of several populations, primarily in the Hudson River, Delaware Bay and Chesapeake Bay. It is equally important to maintain individual stock at healthy level so that over-fishing does not occur at the local level. For that purpose we report estimates of fishing mortality and population characteristics for each individual stock. The full assessment can be found in Kahn (2003). The recreational catch is presented in **Figure 5.5-1 a**. **Over the past 5 years the striped bass harvest has stayed at approximately 2,500,000 to 3,500,000 fish.** Only the status of the Delaware Bay Stock will be discussed below.

The Delaware River Fishing mortality utilizes tag-recapture data in two analyses, a Petersen exploitation estimate and an estimate of F based on survival modeling with MARK program software. The two sets of estimates have been the highest on the east coast of the United States for the last several years. Both estimates, when translated into F (fishing mortality), are F weighted by N (natural mortality). The exploitation estimate for 2002 was 24%, which translates into F2001 = 0.29. The 2002 F estimate from the MARK program with trend models included was F2002 = 0.37.

If trend models are eliminated, the MARK estimate is F_{2002} = 0.26.

Striped Bass spawning stock

The spawning stock survey occurs in April and May on the spawning grounds in the tidal freshwater Delaware River from Wilmington through Philadelphia. Two agencies co-operate in this survey, which tags fish and develops Catch per Unit Effort estimates of abundance in standardized surveys. The Delaware Division of Fish and Wildlife (DDFW) employs electrofishing gear in a formal systematic sampling design (this type of design is randomized), while the Pennsylvania Fish and Boat Commission (PFBC) also employs electrofishing gear, but in a fixed design. Trends in overall abundance are flat from 1995-2001 for the PFBC and indicate a slow decline in the DDFW estimates for the period 1996-2002. However, the 2003 samples had an increase in mean catch per station. Catch rate of females in particular was markedly increased over recent years. Females of age 10 (1993 year class) were the most abundant. Males ranged to over 1000 mm, with ages to 16 years. Overall abundance of males appeared lower than females. Recent years have seen larger catches of larger males with a decline in catches of smaller males.

Recruitment

The New York and New Jersey Striped Bass juvenile indices are presented in **Figure 5.5-2.a.b.** Both indices suggest a decline in 2002. A YOY survey for striped bass is conducted annually by the New Jersey Division of Fish, Game, and Wildlife using beach seine gear. The geometric mean index was extremely low at the beginning of the time series in 1980, and then gradually climbed to a value of 1.03 in 1989. Since then, it has fluctuated without trend between about 1.00 and 2.00. The 2002 index was low, at 0.51 (see **Figures 5.5-2, 5.5-3 and 5.5-4**), but the 2003 index will apparently be a record high value. The Delaware River stock suffers high levels of entrainment mortality from the Salem Nuclear Generating Station. This mortality on YOY larvae and juveniles has been estimated as averaging 32% per year, in the worst case of no compensatory increase in survival of those YOY fish escaping entrainment and impingement (Kahn 2003).

The results of the VPA analysis indicate that the overall fishing mortality (0.35) for fully-recruited ages 8-11 in 2002 exceeded the F target of 0.30, but the population is not over fished since F is below the threshold of 0.41. Recruitment of age 1 bass was at record levels in 2001 and 2002, but may be low in 2003. The spawning stock biomass estimates are at the highest level in the time series, but appear to be leveling-off. Removals by the recreational fishery (harvest and dead discards) are high but may be declining.

Kahn (2003) noted several sources of uncertainty associated with the estimation of survival and recovery parameters in the tagging analysis for striped bass. The uncertainty associated with ageing striped bass with scales still remains a problem. Attendees of the ASMFC striped bass ageing workshop in March, 2003 made many recommendations on how to improve scale impressions, but also agreed that ageing bias is an issue after ages 10-12. Recommendations to develop conversion keys using scale-otolith ages, or to use otoliths as a primary ageing structure were made, and a subcommittee was formed to determine the feasibility of using either approach. Some members of the ASMFC Technical Committee were concerned that the VPA is not adequately robust when dealing with a mixed stock such as coastal striped bass. It is possible that the assumption of mixing and dispersal is not being adequately met to provide a comprehensive estimate of mortality. Some members of the ASMFC Technical Committee were concerned that the distribution of larger striped bass has shifted to offshore waters as the population has increased in abundance. Since the EEZ is closed to harvest and there is limited fishery independent survey data for older striped bass beyond state waters, these fish may not be represented in the assessment. The Technical Committee of ASMFC has begun to conduct additional analyses to reduce the number of indices used in the assessment, and criteria are being developed that would be objectively used for the inclusion/exclusion of current and future indices (Kahn 2003).

5.6 Weakfish

The Delaware Estuary provides a vital spawning and nursery habitat for weakfish, and is one of the most economically important fishery resources in the Delaware Bay.

Figure 5.6-1 presents the weakfish catch by year (all ages) for the period 1966-2002 (Stewart Michels, DNREC, personal communication). From a relative abundance of approximately 30 in 1991 and 50 in 1992, the catch increased to a high of approximately 310 in 1997. It fell by more than half – to 150 – in 1998, however, and dropped again in 1999 to approximately 130. Over the report period the abundance level has ranged from approximately 220 weakfish per nautical mile in 2001 to 100 in 2002 (the last year reported). Some of the fluctuation in abundance may be due to changes in fishing pressure. From the 1950s to the present, the weakfish has been one of the most desired recreational and commercial species in the Delaware Bay. In addition, the weakfish population may have benefited from the decimation of the menhaden populations in the late 1950s (Killam and Richkus, 1992).

The weakfish young of the year indices are presented on **Figure 5.6-2**. Over this report period the YOY ranged from a mean catch / tow of 11 to 8 juveniles in 2002.

5.7 Atlantic sturgeon

A yearly tag and recapture program for Atlantic sturgeon in the lower Delaware River was conducted by the State of Delaware from 1991 through 1998. An estimate of the annual population of primarily sub-adult Atlantic sturgeon utilizing the lower Delaware River declined from 5,600 in 1991 to a low of 862 individuals in 1995. Population estimates were not calculated from 1996 through 1998 due to the absence of recaptures and obvious violations of several critical assumptions of the mark and recaptures methodology. Tag returns from a variety of commercial fisheries extending from southern Maine to Cape Hatteras, North Carolina delineated probable migratory patterns of sub-adult sturgeon that had utilized the Delaware River Estuary for at least some portion of their life history.

Beginning in 1996 and continuing through 1998, sturgeon were tagged with sonic transmitters and their movements were monitored throughout the summer and early fall. One of the benefits of this program was the identification of an additional area where numerous sturgeons tend to concentrate for a prolonged period during the summer. This area extended from roughly Oldmans Point downriver to the vicinity of the Delaware Memorial Bridge. Both shortnose sturgeon and Atlantic sturgeon were taken in this reach of the River in follow-up gill net collections.

The focus of sturgeon sampling efforts has been adjusted to delineate the abundance of juvenile or pre-migratory age classes of Atlantic sturgeon as recommended in the ASMFC management plan. These studies employ the use of relatively small mesh gill nets and sample throughout the summer at the two locations where sturgeon were found to concentrate in the telemetry studies. This program was first conducted in 2001 and is being repeated during 2004. The levels for 2001 show levels similar to those of 1997 (see **Figure 5.7-1**) (source: Craig Shirey, DE Division of Fish and Wildlife, personal communication).

5.8 Short Nosed Sturgeon

Mark and recapture studies are currently under way to assess the size of the shortnose sturgeon population in Delaware Bay. The work is being funded through NOAA and the USACOE.

5.9 American eel

American eels (*Anguilla rostrata*) are abundant and wide spread in the Delaware Estuary. Eels live most of their life in freshwater and brackish water, leaving only to breed in the Sargasso Sea (located in the Central North Atlantic Ocean), after which the adults die. The larvae drift at sea for a time, and then metamorphose into glass eels and migrate to near shore waters. As the eels move upstream they become pigmented and are known as elvers. As they grow and become adult like they become known as yellow eels. After living for 2 to 4 years in freshwater and brackish water, they become sexually mature and finally metamorphose into silver eels in preparation for their migration back to the Sargasso Sea.

Eels were an important food resource for Native Americans and later the colonists. By the late 1960s, export of American eels to Europe and Asia began to increase, due to declines in those populations. During the mid 1970s and again in the mid 1990s, harvest of glass eels and elvers also increased to satisfy Asian markets. In 1995, the Atlantic States Marine Fisheries Commission (ASMFC) began development of an Interstate Fishery Management Plan for eel, due to concerns that eel's life history made it vulnerable to overexploitation and that some data indicated declines in portions of their range. In 2000 the Fishery Management Plan (FMP) was established, which includes harvest, reporting, and monitoring requirements. The Plan manages eels on a coast-wide basis.

Both New Jersey and Delaware allow commercial harvest for eel. Commercial Landings, in pounds, were as follows:

Year	Delaware	New Jersey	Total
2000	119,180	45,393	164,573
2001	121,513	57,700	179,213
2002	89,381	64,600	153,981
2003	155,516	unavailable	

Note: These landings represent state wide totals, which include landings from outside the Delaware River Basin.

All three states (Delaware, New Jersey, and Pennsylvania) allow recreational harvest. This harvest is relatively small and is believed to be declining. In addition the states conduct annual fishery independent young-of-the-year abundance surveys.

These surveys are designed to assess coast-wide annual recruitment. Survey locations for New Jersey and Delaware are outside the drainage basin of the Delaware River. The total numbers of eels captured during the surveys are as follows:

Year	Delaware	New Jersey	Pennsylvania
2000	151,176		98
2001	343,066	8,141	No Survey
2002	216,657	61,090	0
2003	81,233	3,206	0
2004	148,642	3,795	6

Notes:

Delaware: Site location is Millsboro Dam on Indian River. The Survey began in 2000, but the survey was started after eel passage had already begun, so numbers do not compare well with later years. In 2003 the low numbers are likely due to unusually cold water temperatures and increased water flow.

New Jersey: Site location is Patcong Creek, Linwood. Although survey work was carried out in 1999 and 2000 were not available in time for this report. Numbers for 2003 and 2004 are preliminary.

Pennsylvania: For 2000 the survey site was Long Hook Creek, Essington. In 2003 and later the survey site is the Fairmount Fish Ladder, Philadelphia.

6.0 HABITAT AND LAND MANAGEMENT

6.1 Habitat

The Delaware Estuary Program contracted with A.D. Marble & Co. for an assessment of non-aquatic habitat within the estuary watersheds, and their report was accepted in December 2002. The data sources used to create the Primary Habitat Unit Map and to perform the subsequent habitat analysis are listed in **Table 6.1-1.** Digital data sets were evaluated to determine which should be used to develop an initial community base map representing habitats and land covers of the entire study area. The guiding principles that were used to determine which data sets to include were:

- Data that was the most up-to-date available;
- Data that could be reasonably transformed into The Nature Conservancy (TNC) Classification System;
- Data which accurately represented the habitats, both spatially and qualitatively, of most importance to the Delaware Estuary Priority Species;
- Data which was comparable among all three states (DE, PA, and NJ); and
- Data sets with a high potential for being updated in the future

The community base map classifications will be referred to as Primary Habitat Units (PHU's). The selected data sets were reclassified into the TNC Classification System. The final community classifications comprising the finished PHU base map and their relative acreages and percentages in the Delaware Estuary Study Area are included in **Table 6.1-2** and **Figure 6.1-1.** The primary base data used to create this PHU base map was the National Land Cover Dataset (NLCD), National Wetland Inventory (NWI) wetland polygons, Delaware Wetland Mapping (SWMP) Data and New Jersey Freshwater Wetland data.

Due to its higher level of detail, state and NWI wetland data was used in place of NLCD wetland data in all cases. The remainder of the base data listed in **Table 6.1-2** was used in subsequent habitat analysis tasks associated with creation of the habitat preference mapping.

Habitat preference mapping

The finished habitat preference mapping represents the combined habitat needs of 83 terrestrial and wetland species or species assemblages, collectively the "Priority Species" residing in the Delaware Estuary Study Area. These 83 Priority Species were obtained from a list that was created by a DELEP Habitat Task Force. Each of the priority species are considered "important enough to the functioning of the Estuary that the ecosystem would lack wholeness or integrity without them." For the purpose of this analysis, only the habitats of terrestrial and wetland species were modeled. The preferred habitat of truly aquatic species, such as fish, was not modeled because the digital data necessary to accurately map their preferred habitat is not available.

The PHU define the broadest level of species habitat preference. For each species, one of the following preference values was assigned to every PHU in the analysis:

- Strongly preferred
- Neutral
- Avoidance

Strongly preferred habitats represent a primary habitat type for the species that is crucial in its life cycle. In the neutral preference, the habitat may not be preferred by this species, but the species would not necessarily avoid this habitat and in some cases, such as lack of primary habitat, the species may even be abundant in the habitat. The avoidance values were reserved for Primary Habitat Units where the species would rarely be found. This process essentially sets up a range of available habitat for each species within the study area, based on land cover and broad vegetative communities defined by the TNC Classification System. This preference assessment is described thoroughly in A.D. Marble (2003).

The results of the habitat preference analysis are shown graphically on the Final Habitat Preference Composite Map (**Figure 6.1-1**) of this report. As this map illustrates, estuarine wetland habitats adjacent to the Delaware Bay and its tidal tributaries have generally received the highest habitat preference rank of "4." Riparian corridors throughout the Study Area often receive this rank as well. These results are not surprising, since many of the 83 Priority species rely very heavily on these two general habitat types. These highest habitat preference areas are often surrounded by regions that received a habitat preference rank of "3" on the Final Habitat Preference Composite Map. Other areas with this rank include certain forested portions of the study area, especially wetland forests and forested land associated with the New Jersey Maurice River, New Jersey Pine Barrens, and certain portions of the Ridge and Valley Province in Pennsylvania.

Regions of low to moderate habitat preference as indicated by ranks of 0 to 2 on the Final Habitat Preference Composite Map include highly developed urban and suburban areas, mining regions, non-forested land, and areas not in close proximity to riparian habitats. Again, these results are not unexpected, considering the habitat needs of the Priority Species as summarized in the Habitat Matrix for Priority Species of the Delaware Estuary.

6.2 Protected Lands

Two of the major factors in the comprehensive planning and protection of habitat and open space in the Delaware Estuary are the size and location of protected lands. Data presented in section 6.2 was collected by the Delaware Valley Planning Commission (DBRPC) for their own purposes and doesn't cover the entire Estuary area however, it provides a valuable indicator of development patterns and provides a stimulus for additional data collection in the future Data available for 2000-03 shows that all three states and most of the counties and local governments within them have invested new resources in the acquisition of land for its aesthetic, habitat and recreation value. Additional protection has been achieved through the substantial action of non-governmental land trusts and other private efforts. There are several gaps in the land protection data that are readily available, but the consequence of many municipal and county bond and dedicated tax investments shows through clearly.

As of 2002 a total of 750,689 acres (public and private) in New Jersey were protected (over 25% of the area of the 11 counties providing data), 52,010 acres in New Castle County, Delaware were protected (over 19%) and 453,982 acres in Pennsylvania were protected (almost 13% of the 11 counties providing data) **(see tables 6.2-1 and 6.2-2).**

Public land

Since 2000, protected public parkland was increased by over 25,000 acres in the 9 county DVRPC Region with the greatest gain attributed to municipal parklands.

Table 6.2-2 shows that protected parklands in three of the 23 counties providing data for 2002 exceeded 25% of the total county land area (including Cape May, with over 32%, and Burlington, with over 28%).

Table 6.2-3 shows that between 2000 and 2003, open space protected by municipalities increased by over 40% in five counties (Burlington, with a 96% increase, Gloucester with a 68% increase, Delaware, with a 56% increase, Mercer, with a 43% increase, and Bucks, with a 42% increase) of the nine counties providing data for this time span. Open space protected by counties increased by more than 30% in two counties (Burlington, with a 66% increase, and Camden, with a 32 % increase) of those same nine counties that provided data for 2000-03.

Private protected land

Table 6.2-1 shows that preserved farmland in the nine counties that provided data for 2000-03 increased by approximately 84% in Chester, 72% in Bucks, 36% in Gloucester and 33% in Burlington County. Open space protected by land trusts and private land owners in those same counties increased by 143% in Burlington County, 76% in Gloucester County and 24% in Mercer County.

Table 6.2-3 shows that protected private lands (i.e. preserved farm land, trust owned and leased lands) in seven of the 23 counties providing data for 2002 exceeded 5% of the total county land area (including Cumberland, with over 10%, Chester, with almost 10%, Salem, with almost 9%, and Berks, with almost 7%).

7.0 IDENTIFICATION OF DATA GAPS

The following discussion identifies in formation needs for both scientific recommendations and additional data:

7.1 Science Gaps

- We need to clearly define eutrophication in quantitative terms of water quality impairment in the Delaware Estuary. The current guidance does not identify the actual effects related to nutrient impacts to the waterbody. This could include documentation regarding nuisance algal blooms and aquatic plants, spatial and temporal extent of fish kills, sporadic water quality impairments etc.

- Additional habitat mapping for the 13 Counties encompassing the Delaware Estuary needs to be provided. This will insure that a clear picture of habitat protection for the entire estuary will be developed.

7.2 Data Needs

- The nutrient loads from groundwater inputs need to be investigated more fully.
- Stimulatory studies of phytoplankton growth to assess limiting nutrients and the potential for nutrient enriched growth.
- We need to promote the use of more automatic monitoring devices in the estuary.
- Protected lands data, estuary wide is needed.
- Improved knowledge of early life history stages for blue crabs (including environmental factors influencing growth and survival).
- Improve fisheries dependent data collection for blue crab.
- Several near-shore areas at the mouth of some tributaries of Delaware Bay need to be monitored more frequently for dissolved oxygen to establish whether water quality standards are being met.
- Validation of hydroaccoustic data regarding American shad abundance estimates.

8.0 MANAGEMENT CONSIDERATIONS

The following are management options for consideration by the Steering Committee of the Delaware Estuary Program:

- Provide for complete and continual updates to resource stock assessment based on the best available scientific information and computer models available.
- Evaluate the biological and socioeconomic effects of controls on fishing gear to discards and by-catch.
- Enhance inter-state resource management efforts and data collection protocols for blue crab.
- Exchange biological and fisheries-related information between Delaware, New Jersey, and the private sector on a regular/continuing basis.
- Coordinate data analysis and establish peer review teams to review stock assessment analyses. Implement comprehensive, complementary management approaches based on cooperative, synchronized efforts from New Jersey and Delaware natural resource agencies.
- Develop a consistent approach to harvest needs. There continues to be significant concern regarding the sustainability of the current horseshoe crab bait harvest by many user groups. However, the management recommendations supported by different user groups varies substantially, from unrestricted harvest to a coastwide cap on landings 60-80% below the reference period landings.
- Avoid increases in fishing effort for blue crab and give consideration to reducing fishing effort. In addition, targeting of mature female crabs in the fishery, particularly when they are concentrated, should be discouraged, in order to protect the spawning stock
- Set a threshold to identify whether resource protection measures need to be pursued with any species whose population is documented as declining over the previous five years.
- Increase coordination and data sharing among environmental groups, regulatory agencies, and officials who are collecting data in the estuary.
- Implement a broad based effort to achieve PCB reductions from point and non-point sources to move towards reduction of fish advisories in the estuary.
- Employ regional approaches for sediment management by improving the beneficial use of dredged materials for habitat restoration.
- Improve coordination and monitoring for invasive species management.

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